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by

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Submitted in Partial Fulfillment

of the Requirements for the Degrees

of

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Submitted to the Department of Ocean Engineering on May 12, 1977 in partial fulfillment of the requirements for the Degrees of Ocean Engineer and Master of Science in Mechanical Engineering

ABSTRACT

A method of predicting local values of heat transfer coefficients in round tubes for forced convection boiling of water with net vapor generation is proposed. The total heat transfer is postulated to be made up of a forced convection component and a nucleate boiling component where it exists.

The forced convection compnnent was correlated by a Traviss (17) theoretical analysis of heat transfer across a thin annular film, modified to fit non-boiling data.

The heat flux required to initiate nucleate boiling was predicted by the equilibrium of a hemispherical vapor bubble in a linear temperature gradient near the wall. The largest equivalent surface cavity radius capable of nucleation was suggested to be of order 10^{-5} feet.

Nucleate boiling correlations of Rohsenow (9), Mikic

(22), and Thom (23) were examined to account for the boiling component. Superposition was accomplished by forcing the boiling component to be zero at the onset of nucleate boiling.

The method was tested against eight sets of water data in vertical up and down flow. The Chen (8) correlation for convective boiling was also tested as a standard. The modified Traviss forced convection/Mikic nucleate boiling had the lowest average percent deviation between predicted and experimental values of wall superheat over all data points of $\pm 15.4\%$.

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NOMENCLATURE

B	Parameter used in incipient boiling analysis, ft^{o}R
B_o	Boiling number, $\frac{q/A}{h_{fg}G}$,
B_M	Constant in Mikic pool boiling analysis
C_p	Specific heat capacity, BTU/lbm-^{o}F
C_{sf}	Constant in Rohsenow nucleate boiling correlation
D	Tube inside diameter, ft.
F	Chen Reynolds number factor, $(Re/Re_l)^{0.8}$
$F(X_{tt})$	Traviss two-phase forced convection parameter, $\frac{NuF_2}{Re_l^{0.9}Pr_l}$
F_2	Traviss velocity profile parameter, Equation (2.4)
F_D	Dengler boiling correction factor, Equation (1.2)
G	Mass flow velocity based on <u>total</u> mass flow rate, lbm/hr-ft^2
g	Acceleration of gravity, $4.173X10^8$ ft/hr^2
g_o	Gravitational constant, $4.173X10^8$ lbm-ft/lbf- r^2
h	Two-phase heat transfer coefficient, BTU/hr-ft^2-^{o}F
h_{fg}	Latent heat of vaporization, BTU/lbm
h_{lo}	Heat transfer coefficient obtained from Dittus-Boelter equation assuming total flow is all liquid, BTU/hr-ft^2-^{o}F

(H-TS)	Gibbs free energy, BTU
k	Thermal conductivity, BTU/hr-ft-^{o}F
m	Constant in Mikic pool boiling correlation
n	Slope of fully developed boiling curve on log-log coordinates
Nu	Nusselt number, $\frac{hD}{k}$
P	Pressure, psia
Pr	Prandtl number, $\frac{C_p\mu}{k}$
q/A	Heat flux, BTU/hr-ft^2-^{o}F
r	Radius of bubble cavity or bubble, ft
R	Gas constant, ft-lbf/lbm-^{o}R
Re_{TP}	Chen two-phase effective Reynolds number
Re_l	Reynolds number for liquid fraction, $\frac{GD(1-x)}{\mu_l}$
S	Chen nucleate boiling suppression factor
T	Temperature, ^{o}F or ^{o}R in difference equations, ^{o}R otherwise
v	Specific volume, ft^3/lbm
W	Constant in Thom subcooled boiling correlation
x	Vapor mass fraction, "quality"
X_{tt}	Martinelli parameter, $\left(\frac{1-x}{x}\right)^{0.9}\left(\frac{\rho_v}{\rho_l}\right)^{0.5}\left(\frac{\mu_l}{\mu_v}\right)^{0.1}$
y	Perpindicular distance away from heated surface, ft
ΔP_{sat}	Difference in vapor pressure corresponding to ΔT_{sat}, lbf/ft^2

ΔT_e	Chen effective superheat with flow, ^oF
ΔT_{sat}	Wall superheat, $(T_w - T_{sat})$, ^oF
μ	Absolute viscosity, lbm/hr-ft
ρ	Density lbm/ft^3
σ	Surface tension, lbf/ft
ϕ	Parameter in Mikic pool boiling correlation

Subscripts

B	Fully developed nucleate boiling
crit	First cavity to nucleate
data	Experimental value
e	Effective value with flow
FC	Forced convection without boiling
fg	Associated with a change of phase
ib	Value at incipient nucleation point
l	Value for liquid
max	Largest cavity potentially active
pred	Predicted value
sat	Value at saturation conditions
TP	Two-phase
try	Iterative trial value
v	Value for vapor
w	Evaluated at wall conditions

TP	Two-phase
try	Iterative trial value
v	Value for saturated vapor
w	Evaluated at the heated wall

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Chapter 1

INTRODUCTION

1.1 General

There are countless applications where the transfer of heat from a surface to a boiling fluid is of great importance. Over the past 30 years many investigators have obtained experimental data, but attempts at describing the mechanisms and predicting heat transfer performance have usually met with limited success. The mass of correlations have in general had little applicability to systems much different from the one used to generate the data.

It has become almost trite to cite the complexities of forced convection boiling phenomena, but since these are at the heart of the difficulty in predicting data, some of the considerations are reviewed in the following paragraphs.

In single phase heat transfer, the heat flux generally varies linearly with the temperature difference, and is well predicted by any of several well known equations (Dittus-Boelter, Sieder-Tate, etc.). In nucleate pool boiling, however, the heat flux typically varies as the cube of the temperature difference, as shown in Figure 1. For non-boiling convection, the hydrodynamic field may be

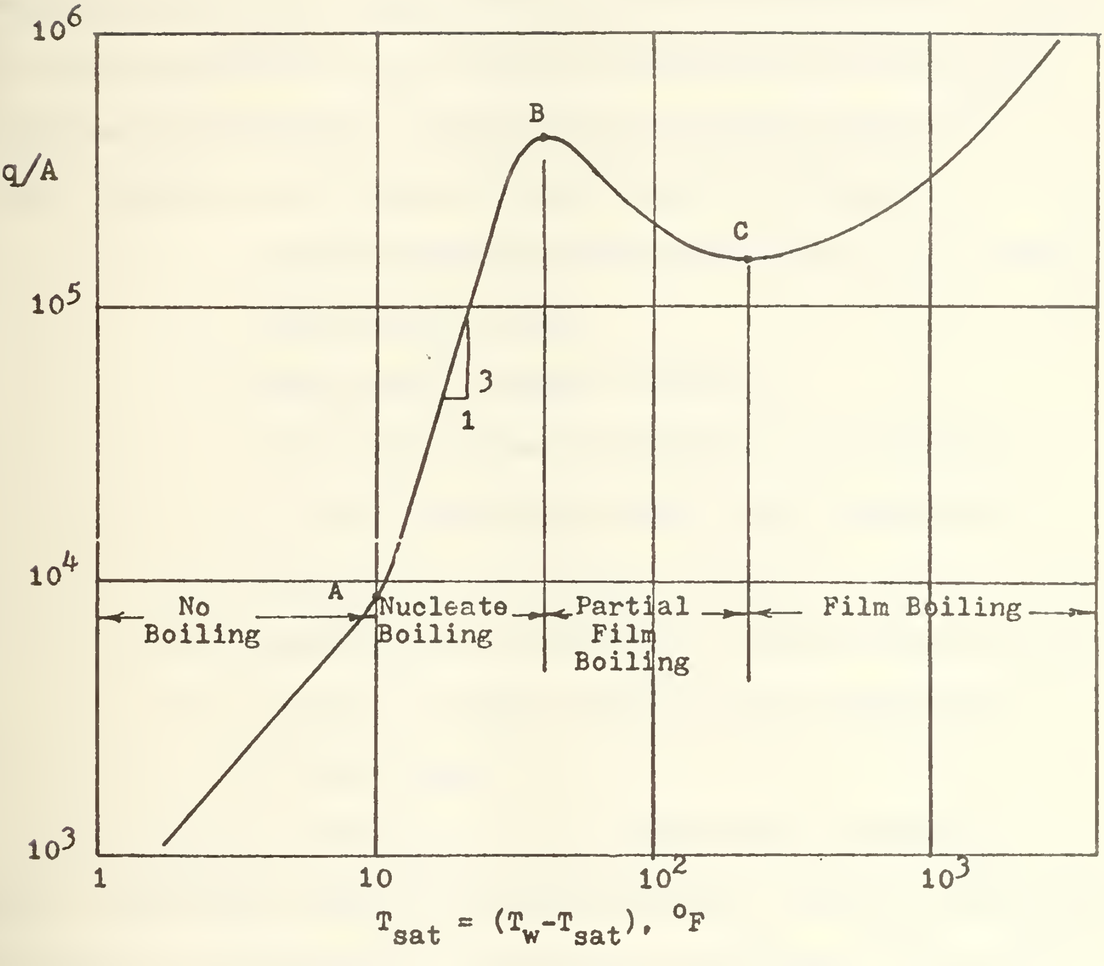

FIGURE 1 Typical Curve for Saturated Pool Boiling

treated independently of the temperature field; but this is not the case for boiling phenomena (5).

The case of convective boiling with net generation of vapor is shown in Figure 2. A vertical tube is heated uniformly over its length and is fed with subcooled liquid at a rate such that the liquid is completely evaporated. Experimental evidence indicates that several modes of heat transfer will occur as vaporization proceeds:

1. Single phase forced convection to the liquid.
2. Subcooled boiling.
3. Saturated nucleate boiling.
4. Two-phase forced convection (evaporation at the liquid film-vapor core interface).
5. Combinations of modes 3 and 4.
6. Transition to a dry wall (liquid deficient).
7. Dry wall (single phase forced convection to the vapor).

In Figure 2 the fluid bulk temperature increases until saturation conditions are reached, and then gradually decreases with decreasing saturation pressure. The wall temperature profile initially increases parallel to the fluid temperature profile. At some point along the tube the conditions adjacent to the wall are such that bubbles of vapor can occur at nucleation sites. This mechanism is known as subcooled boiling. Because the liquid is subcooled (i.e. the bulk mean temperature is less than the saturation

temperature), any vapor bubbles that detach from the wall are condensed in the colder core liquid. As subcooled boiling begins, the wall temperature tends toward a constant value in accordance with the experimental observations that the heat flux in this region is a strong function of the wall superheat, $T_w - T_{sat}$, alone.

The transition from subcooled to saturated nucleate boiling occurs when the thermodynamic mixed mean enthalpy equals the saturation enthalpy (x=0.). At this point, there is still subcooled liquid in the core, which reaches the saturation temperature somewhat downstream. Vapor generated can then exist anywhere in the liquid stream, and the bubbles can then begin to coalesce to form the slug flow pattern, which progresses into the annular flow regime with increasing vapor quality.

As the quality increases through the saturated boiling region, a point is reached where the principal mechanism changes from one of boiling, to one of evaporation at the liquid-vapor interface. This is due primarily to the establishment of a stable annular climbing liquid film and a vapor core, with or without entrained liquid droplets. The effective thermal conductivity of the thin liquid film on the tube wall is so high that insufficient wall superheat exists to allow further nucleation. Since boiling is suppressed, this region

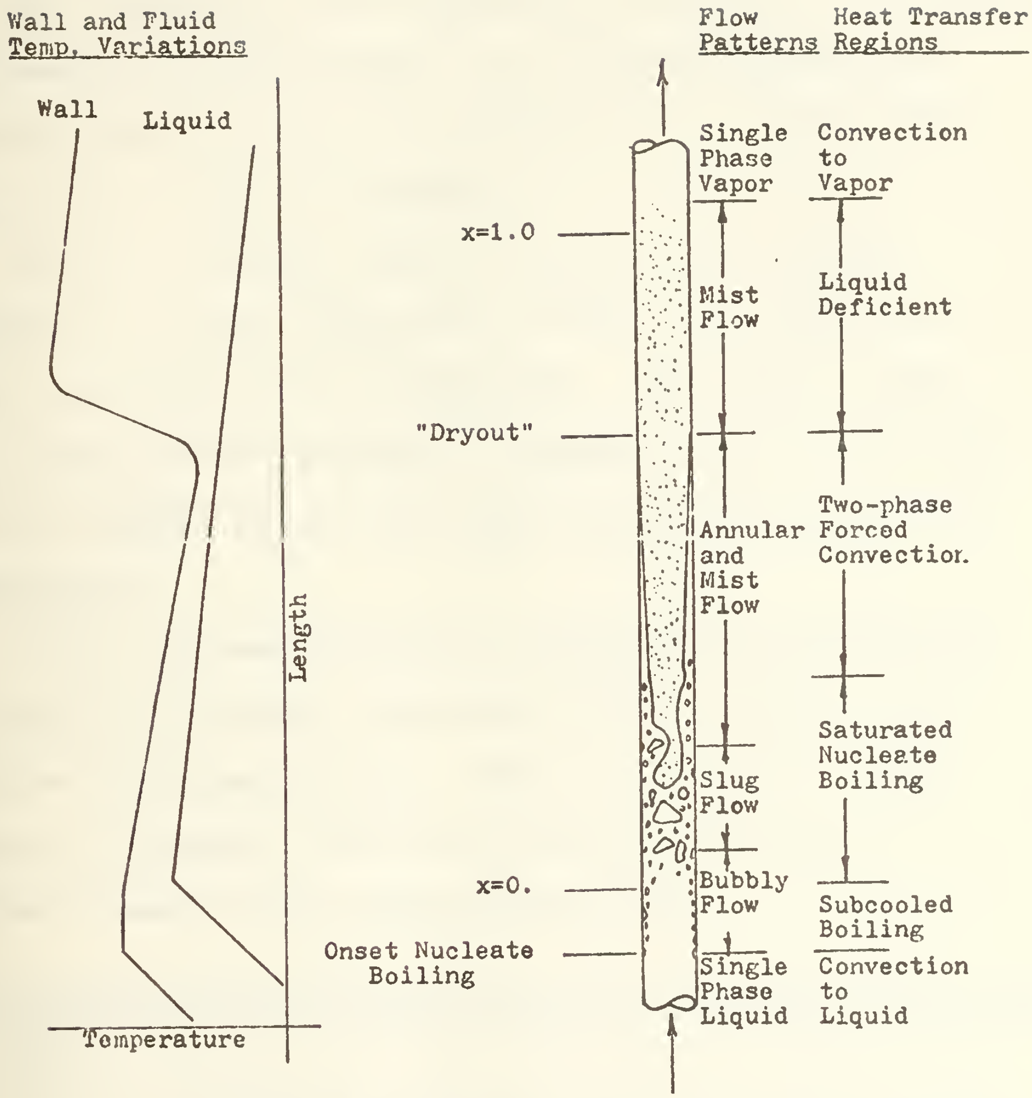

FIGURE 2 Heat Transfer Conditions for Forced Convection Boiling in a Tube

is called the two-phase forced convection region of heat transfer. As the vaporization proceeds, the heat transfer coefficient increases with quality, and very high values may be produced, with Nusselt numbers of order 1000 common.

The transition from principally boiling to principally evaporating is complicated and is highly dependent on both the flow and heat flux parameters. A further discussion will follow in Chapter 2.

At some critical value of quality the complete evaporation of the liquid film occurs, resulting in a sharp rise in the wall temperature. The wall is then only intermittently wetted by entrained liquid droplets. Past the dryout point, the vapor may become considerably superheated.

There has been relatively little work specifically in the area of forced convection boiling inside a duct, with net vapor generation. Since this is the primary region of interest, the next section will present a review of some of the better known work.

1.2 Previous Work in Forced Convection Boiling of Saturated Water

Mumm (1) measured local heat transfer coefficients at the exit of a 0.465 in. inside diameter electrically heated stainless steel tube for net boiling of water with exit qualities up to 70%. The data for qualities less than 40% were correlated by the equation:

$$Nu = \left[4.3 + 0.0005\left(\frac{v_{fg}}{v_1}\right)^{1.64} x\right]\frac{q/A}{Gh_{fg}} \quad Re^{0.808} \qquad (1.1)$$

Dengler (2) in 1952 obtained local heat transfer coefficients for water in vertical upflow through a 1 inch inside diameter tube, heated by steam jackets. Heat transfer coefficients were measured for exit qualities up to 80%. It was postulated that the heat transfer in forced convection boiling is influenced by the usual forced convection effect and a nucleate boiling effect when it occurs. At high qualities an increased forced convection effect due to the high vapor velocity suppresses the nucleation. The rapid increase in volumetric fraction of the vapor for small increases in mass quality at low and moderate pressures stabilizes the annular flow regime even at low qualities. Dengler proposed the following correlation:

$$\frac{h}{h_{lo}} = 3.5\,(X_{tt})^{-0.5}F_D\ , \qquad (1.2)$$

wher h_{lo} is the nonboiling heat transfer coefficient for the liquid at the local state and the same total mass flow rate obtained from the Dittus-Boelter equation.

$$h_{lo} = 0.023\left(\frac{k_l}{D}\right)\left(\frac{DG}{\mu_l}\right)^{0.8}(Pr_l)^{0.4} \qquad (1.3)$$

X_{tt} is the Martinelli parameter widely used for the correlation of pressure drop data:

$$X_{tt} = \left(\frac{\rho v}{\rho_1}\right)^{0.5}\left(\frac{\mu_1}{\mu_v}\right)^{0.1}\left(\frac{1-x}{x}\right)^{0.9} \tag{1.4}$$

F_D represents the correlation factor for conditions where nucleate boiling exists.

In 1960, Sani (3) presented data for water in vertical downflow in an electrically heated 0.7194 inch inside diameter tube. He compared his data with existing correlations, but found the deviations substantial.

In 1962, Schrock and Grossman (4,5) published a report on forced convection vertical upflow boiling of water in several electrically heated tubes. They derived an expression similar to Dengler's for the two-phase forced convection region, but introduced the boiling number, B_o, as the extra variable to account for the heat transfer enhancement of nucleation. Their correlation is of the form:

$$\frac{h}{h_{lo}} = 7400\ B_o + 0.00015(X_{tt})^{-0.67}\ , \tag{1.5}$$

where X_{tt} and h_{lo} are defined as before, and

$$B_o = \frac{q/A}{Gh_{fg}}\ . \tag{1.6}$$

Wright (6) followed Sani's work in downflow boiling, and extended the range of flow and heat flux parameters.

Bertoletti et al (7) obtained heat transfer data for steady and transient conditions for vertical upflow of water at 1000 psia in electrically heated tubes. Although

their experiments attempted to determine the critical heat flux for a variety of conditions, the behavior for heat fluxes less than critical was also explored.

Chen (8) recognized that there was little consistency among the correlations that he examined for water and organic fluids, and that none were satisfactory for general use. He then proposed a new correlation which proved very successful in predicting the forced convection boiling heat transfer data he examined. In particular, for the water data of Dengler, Schrock and Grossman, and Sani, he was able to significantly improve upon the correlations proposed by the investigators for their own data. This is summarized in Table 1.

Chen's correlation covers both the saturated nucleate boiling region and the two-phase forced convection region. It was assumed that <u>both</u> mechanisms occur to some degree over the entire range, and that the contributions were additive. This method of superposition was first proposed by Rohsenow (9). Chen argued that the total heat transfer coefficient could be represented by:

$$h = h_{mac} + h_{mic} \tag{1.6}$$

It was assumed that the convective component, h_{mac} could be correlated by the Dittus-Boelter equation:

$$h_{mac} = 0.023 Re_{TP}^{0.8} Pr_{TP}^{0.4} \; \frac{k_{TP}}{D} \; , \tag{1.7}$$

where the Reynolds number, Prandtl number, and thermal conductivity are associated with the two-phase fluid. Since the heat is ultimately carried through a liquid film in annular flow, Chen used the liquid property values.

Chen defined a factor, F, such that:

$$F = \left(\frac{Re_{TP}}{Re_l}\right)^{0.8} = \left(\frac{Re_{TP}}{\frac{GD(1-x)}{\mu_l}}\right)^{0.8} \qquad (1.8)$$

Equation (1.7) then becomes:

$$h_{mac} = 0.023 Re_l^{0.8} Pr_l^{0.4} \frac{k_l}{D} F \qquad (1.9)$$

The only unknown factor is the expression for F, a flow parameter only, and which Chen suggested would be a function of the Martinelli parameter.

Chen modified the pool boiling analysis of Forster and Zuber for the evaluation of h_{mic}, the nucleate boiling component. Chen proposed the following for the boiling contribution:

$$h_{mic} = 0.00122 \frac{k_l^{0.79} c_{pl}^{0.45} \rho_l^{0.49} g_o^{0.25}}{\sigma^{0.5} \mu_l^{0.29} h_{fg}^{0.24} \rho_v^{0.24}} \Delta T_e^{0.24} \Delta P_e^{0.75} \qquad (1.10)$$

Because both in pool boiling and forced convection boiling the actual superheat is not constant, but decreases with distance from the wall, the mean superheat, ΔT_e, in which the bubble grows, is less than the wall superheat, ΔT_{sat}. For pool boiling, this difference is small, but Chen

postulated it could not be neglected in forced convection boiling. He then defined a suppression factor, S, such that:

$$S = \frac{\Delta T_e}{\Delta T_{sat}}^{0.99} \tag{1.11}$$

Using the Clausius-Clapeyron relation, Equation (1.11) can be rewritten:

$$S = \left(\frac{\Delta T_e}{\Delta T_{sat}}\right)^{0.24}\left(\frac{\Delta P_e}{\Delta P_{sat}}\right)^{0.75}, \tag{1.12}$$

and Equation (1.10) may then be rewritten as:

$$h_{mic} = 0.00122 \; \frac{k_l^{\;0.79} c_{pl}^{\;0.45} \rho_l^{\;0.49} g_o^{\;0.25}}{\sigma^{0.5} \mu_l^{\;0.29} h_{fg}^{\;0.24} \rho_v^{\;0.24}} \; \Delta T_{sat}^{\;0.24} \Delta P_{sat}^{\;0.75} \; S \tag{1.13}$$

$$\Delta P_{sat} = \left(\frac{dP}{dT}_{sat}\right) \Delta T_{sat} \tag{1.14}$$

Chen further postulated that S could be represented as a function of the two-phase Reynolds number, and would approach unity at low flow rates and zero at high flow rates. He then determined the F and S functions empirically from experimental data using an iterative procedure to obtain the best fit. These functions are shown in Figures 3 and 4.

Chen's correlation is at present the best available for the saturated forced convection boiling region (10). While it is based on physical reasoning with respect to the way in which the forced convection and boiling

	Average % Deviation For Correlations		
Data	Dengler	Schrock & Grossman	Chen
Dengler	30.5	20.3	14.7
Schrock & Grossman	89.5	20.0	15.1
Sani	26.9	48.6	8.5
Average	49.0	29.6	12.8

TABLE 1

Comparison of Correlations with Chen's Data Base

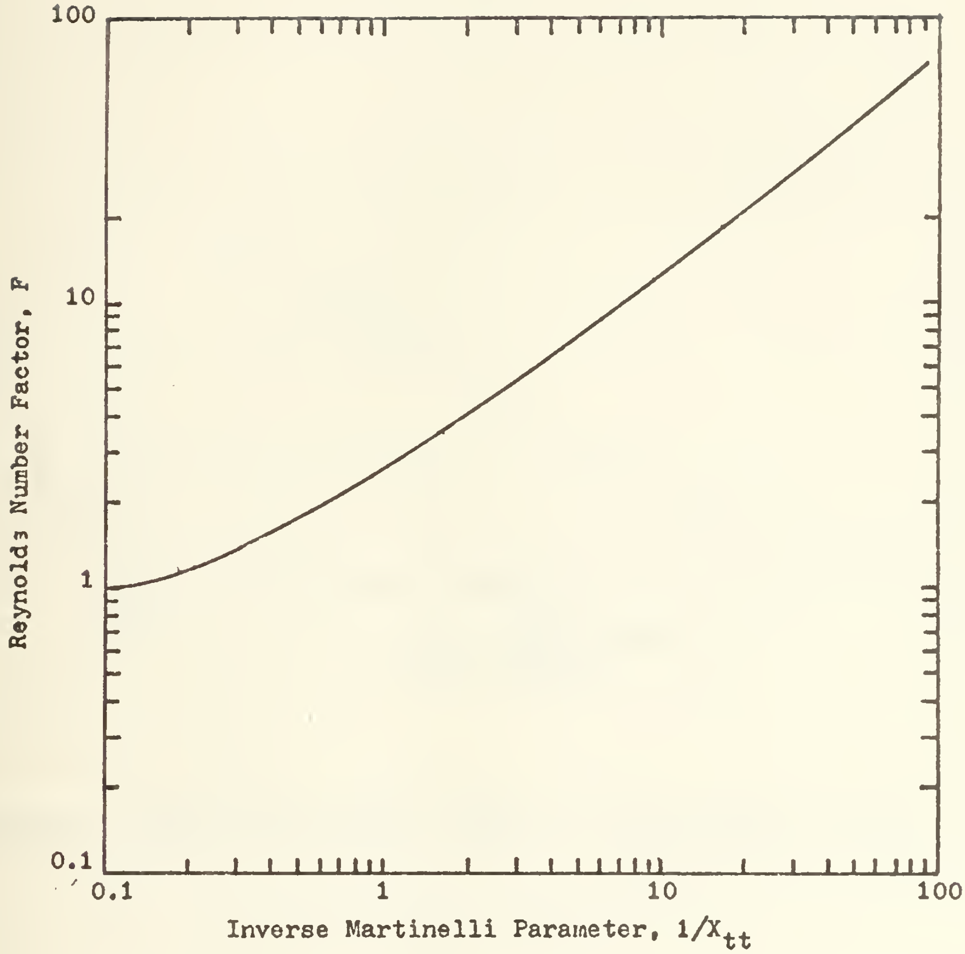

FIGURE 3 Chen's Reynolds Factor, F

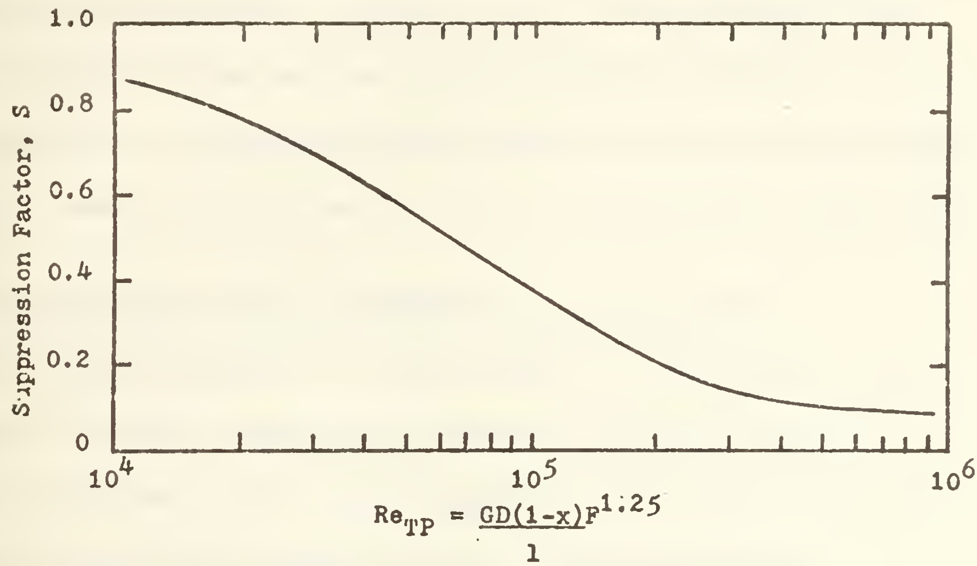

FIGURE 4 Chen's Nucleate Boiling Suppression Factor, S

contributions are superposed, the F and S functions are purely empirical relations. In the case of forced convection, a number of analytical attempts have been made to describe the fluid mechanics and resulting heat transfer that occurs with an annular flow model (11,12). Additionally, considerable work in theoretical models has been done in condensation research (13,14,15,16), and although the phase distributions may be considerably different for condensation, the theoretical models should give results that are easily corrected to fit any particular data set.

1.3 Purpose and Basic Assumptions of Analysis

It is the purpose of this study to develop a correlation for the saturated nucleate boiling regions using a different and less empirical approach than Chen for superposing the effect of the two components. A comparison will also be made with Chen's original water data, as well as additional data sets not specifically used by him in the development of his correlation.

In particular, the region of interest will be defined by:

1. Saturated, two-phase convective flow of water.
2. Vertical, axial flow in round tubes.
3. Stable flow.
4. No slug flow.
5. No liquid deficiency.

6. Heat flux less than critical flux.

Typically these conditions correspond to annular flow or annular flow with entrainment at low and moderate pressures, in the quality rage of 1% to 70% (8).

Chapter 2

DEVELOPMENT OF THE CORRELATION

2.1 General Approach to the Analysis

In the previous chapter, the correlation of Chen, involving a forced convection and a nucleate boiling component was shown to be very successful in predicting two-phase heat transfer data. The overall approach used in this analysis will be similar to Chen's, i.e., an additive superposition technique to account separately for the forced convection and boiling, but where the effect of convection on the point of incipient boiling is accounted for.

The method requires the separate consideration of four aspects of the total heat transfer mechanism:

1. Selection of the forced convection correlation.
2. Location of the incipient boiling point.
3. Selection of the nucleate boiling curve to be used.
4. Proper addition of the convection and boiling contributions.

2.2 Forced Convection Contribution

Traviss, Rohsenow, and Baron (17) developed a correlation for forced convection condensation inside tubes. An annular flow model was used, with the momentum-heat transfer analogy using the von Karman universal velocity

distribution to describe the liquid film. The vapor core was assumed to be very turbulent, and the temperature in the vapor core and at the liquid-vapor interface was assumed equal to the local saturation temperature. An order of magnitude analysis and non-dimensionalization of the heat transfer equations resulted in a simple formulation for the local heat transfer coefficient. Their final correlation is of the form:

$$h_{FC} = \frac{F(X_{tt})Re_1^{0.9}Pr_1}{F_2}\ \frac{k_1}{D} \qquad (2.1)$$

where

$$Re_1 = \frac{GD(1-x)}{\mu_1} \qquad (2.2)$$

$$F(X_{tt}) = 0.15(1/X_{tt} + 2.85/X_{tt}^{0.476}) \qquad (2.3)$$

and X_{tt} is the Martinelli parameter.

$$F_2 = 5Pr_1 + 5\ln(1+5Pr_1) + 2.5\ln(0.00313Re_1^{0.812}) \qquad (2.4)$$

The correlation was very successful in predicting condensation data for Freon 12 and 22. It was felt that such a correlation based on the theoretical analysis of the annular flow model would be useful for evaporation data as well, although some correction might be required. Collier (10) noted that the heat transfer coefficients predicted from other analyses for evaporation similar to Traviss' were higher than actually observed. Hewitt and Hall-Taylor (18) recommended that the heat transfer coefficient used for design be about 30% less than that

predicted from the theoretical models.

In order to determine how much, if any, the Traviss forced convection correlation overpredicts actual data, it is necessary to compare it with data for which there is no nucleate boiling. In order to accomplish this, the development of an incipient boiling criteria is required.

2.3 Incipient Boiling Criteria

It is well accepted that in boiling systems, bubbles originate at nucleation sites corresponding to cavities on the heated surface in which vapor or other gases have been trapped. If these sites are modeled as simple conical cavities, a bubble will pass through a hemispherical state with a radius equal to the cavity mouth radius as it grows. For this bubble of vapor to exist, three equilibrium conditions must be met at the interface:

1. Mechanical $(P_v - P_l) = \dfrac{2\sigma}{r}$ (2.5a)

2. Thermal $T_v = T_l$ (2.5b)

3. Thermodynamic $(H\text{-}TS)_v = (H\text{-}TS)_l$ (2.5c)

Since P_v is greater than P_l, and T_v is equal to T_l, the liquid must be superheated. The minimum vapor temperature necessary for the existence of a hemispherical bubble is determined by calculating the difference $T_v - T_{sat}$ at the vapor pressure (See Figure 5). This vapor superheat may be related along the saturation line

with the use of the Clausius-Clapeyron equation which relates the temperature and pressure of two phases in equilibrium with the latent heat and volume change for a change of phase:

$$\frac{h_{fg}}{v_{fg}} = T\left(\frac{dP}{dT}\right)_{sat} \qquad (2.6)$$

To integrate Equation (2.6), the following assumptions will be made:

1. $v_{fg} \simeq v_v$
2. $v_v \simeq \frac{R_v T}{P}$
3. $\frac{h_{fg}}{R_v} \simeq \text{constant}$

Then $$\int_{P_l}^{P_v} \frac{dP}{P} = \frac{h_{fg}}{R_v} \int_{T_{sat}}^{T_v} \frac{dT}{T^2}$$

$$\ln\left(\frac{P_v}{P_l}\right) = \frac{h_{fg}}{R_v}\left(\frac{1}{T_{sat}} - \frac{1}{T_v}\right) \qquad (2.7)$$

Substituting Equation (2.5a) into Equation (2.7) and rearranging:

$$(T_v - T_{sat}) = \frac{T_v T_{sat} R_v}{h_{fg}} \ln\left(1 + \frac{2\sigma}{P_l r}\right) \qquad (2.8)$$

where the properties are evaluated at the local saturation conditions.

Equation (2.8) represents the locus of stable bubble radii in a uniform temperature field. If the bubble is

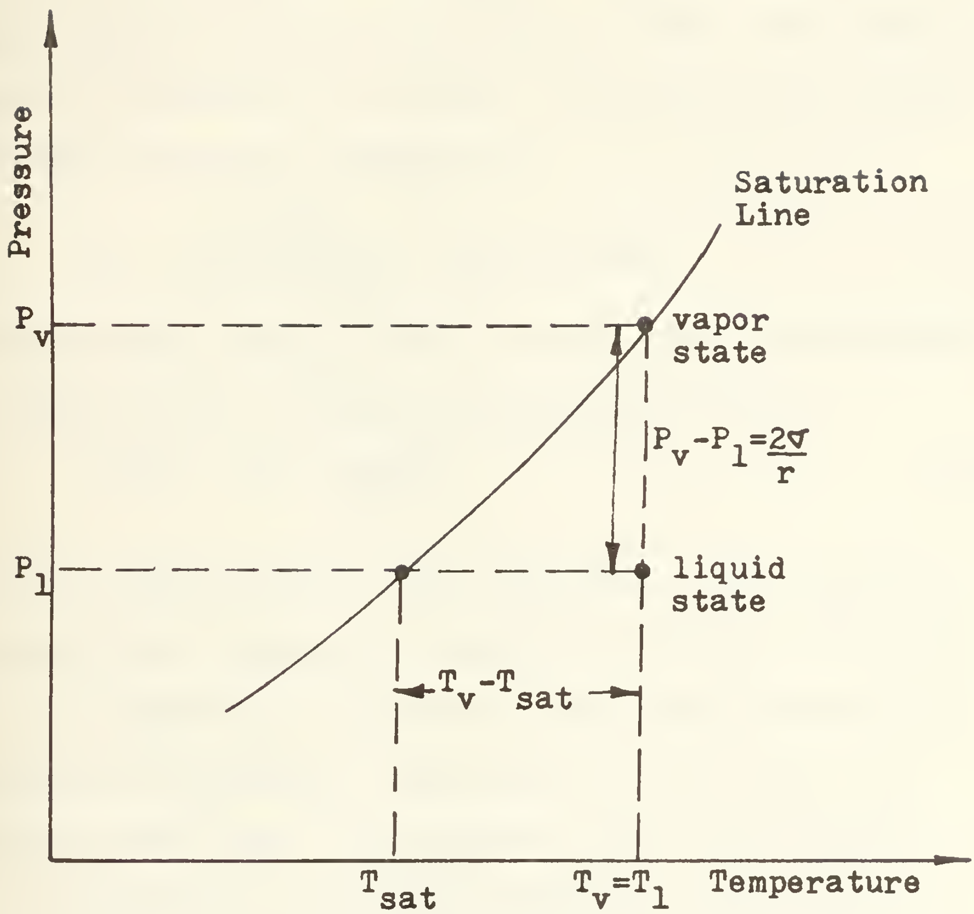

FIGURE 5 Relation Between Vapor and Liquid States for Stable Bubble Radii

to grow from its hemispherical state at the cavity mouth, there must be net heat transfer to the bubble, and the temperature in the liquid layer near the wall must equal or exceed T_v calculated from Equation (2.8).

The following procedure to predict intiation of boiling was developed by Bergles and Rohsenow (19). The temperature gradient in terms of the forced convection heat transfer coefficient and wall superheat is:

$$\frac{q}{A} = -k_l \left(\frac{\partial T}{\partial y}\right)_{y=0} = h_{FC}(T_w - T_{sat}) \tag{2.9}$$

The temperature profile near the wall may be approximated in a linear form by integrating Equation (2.9):

$$T_l(y) = T_w - \left(\frac{q/A}{k_l}\right) y \tag{2.10}$$

For a given set of flow conditions, both the wall temperature and temperature gradient increase with heat flux. In Figure 6, a series of lines representing the temperature distribution near the wall are shown for increasing heat flux. Also shown is the equilibrium vapor temperature expressed by Equation (2.8), with the cavity radius plotted as distance from the wall.

The postulated criterion is that nucleation is initiated when the temperature gradient is tangent to the curve represented by Equation (2.8), implying that the liquid temperature equals or exceeds the critical value required to nucleate a cavity of radius r_{crit} over the entire bubble surface. A slight increase in

heat flux would activate cavities in the size $y_1 < r < y_2$.

Numerical estimates of the heat flux required to initiate the critical cavity radius may be made by solving at the point of tangency:

$$T_l(y) = T_v \tag{2.11}$$

$$\frac{dT_l}{dy} = \frac{dT_v}{dr} \tag{2.12}$$

Davis and Anderson (20) obtained an analytical solution to quations (2.11) and (2.12) with the following results:

$$r_{crit} = \left(\frac{Bk_l}{q/A_{ib}} \right)^{0.5} \tag{2.13}$$

$$(T_w - T_{sat})_{ib} = \frac{B}{r_{crit}} + \frac{(q/A)_{ib} r_{crit}}{k_l} \tag{2.14}$$

$$(q/A)_{ib} = \frac{k_l}{4B}(T_w - T_{sat})^2_{ib} \tag{2.15}$$

where $$B = \frac{2\sigma T_{sat} v_{fg}}{h_{fg}} \tag{2.16}$$

At the onset of nucleate boiling:

$$(q/A)_{ib} = h_{FC}(T_w - T_{sat})_{ib} \tag{2.17}$$

Solving Equations (2.15) and (2.17) simultaneously yields:

$$(q/A)_{ib} = \frac{4B}{k_l}(h_{FC})^2 \tag{2.18}$$

$$(T_w - T_{sat})_{ib} = \frac{4B}{k_l} h_{FC} \tag{2.19}$$

The finish of the heating surface can influence the boiling curve; the following arguments are best discussed

with reference to Figures 7 and 8.

Figure 7 demonstrates the comparison of rough and smooth surfaces which have low non-boiling heat transfer coefficients (e.g. natural convection). Under these conditions, the wall superheats are relatively high even at low heat flux levels, and the liquid temperature gradients have a shallow slope. As a result, the initial point of tangency will occur at a very large cavity size. If this cavity contained trapped gas or vapor, it could nucleate. The smooth surface has no cavities in this size range and does not nucleate. A slight increase in heat flux to q/A_2 would allow nucleation of the largest cavity on the smooth surface, but many of the cavities on the rough surface would have been activated with the result that boiling would be well established on the boiling curve. A higher heat flux, q/A_3, would activate more cavities on the smooth surface, and would cause the boiling on the rough surface to become even more intense. As a result, two distinct boiling curves of similar slope would emerge, with the smooth surface curve shifted to the right of the rough surface curve.

For forced convection with high non-boiling heat transfer coefficients, high heat fluxes produce relatively low wall superheats, and steeper liquid temperature profiles. This results in the initial tangency to occur at an intermediate cavity size which may be present on both rough

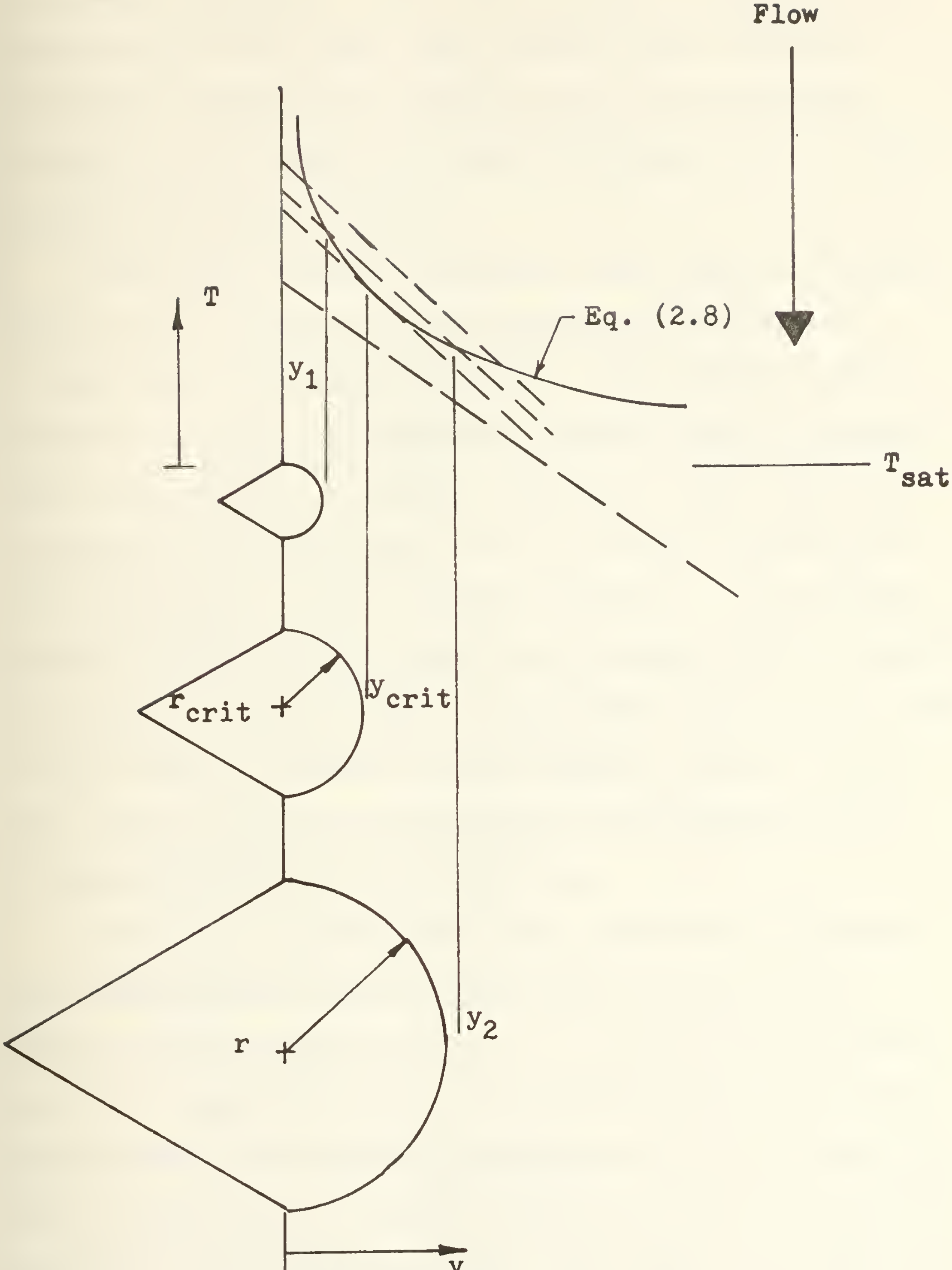

FIGURE 6 Temperature Distribution Around a Bubble Nucleation Site on a Heated Surface

and smooth surfaces. Then the incipient boiling point would occur at the same heat flux for both surfaces. Increasing the heat flux would tend to activate more cavities on both surfaces, with the result that a single boiling curve would emerge.

The above treatment assumes a wide range of "active" cavity sizes (residual trapped vapor or gas present). In high velocity forced convection, the maximum active cavity size may be considerably smaller than the maximum size obtained from a surface inspection only. Then the inception of boiling would occur at higher fluxes than that predicted from the initial tangency. One possible reason for this is the inability of large, shallow cavities to sustain a trapped vapor pocket under high velocity flow. In this case an estimate of the largest "active" cavity size must be made and substituted into Equation (2.13) to determine the required heat flux.

Davis and Anderson (20) found reasonable agreement with experimental data for water and benzene when a maximum active cavity size of 1μ (3.3×10^{-6} ft.) was used. Brown (21) measured cavity size distributions on various experimental and commercial surfaces and found reasonably dense populations of cavities (greater than one site/cm^2) occur only for equivalent radii less than 10μ (3.3×10^{-5} ft.) (10). It is felt that these two values represent a range for the size of the largest potentially active cavity.

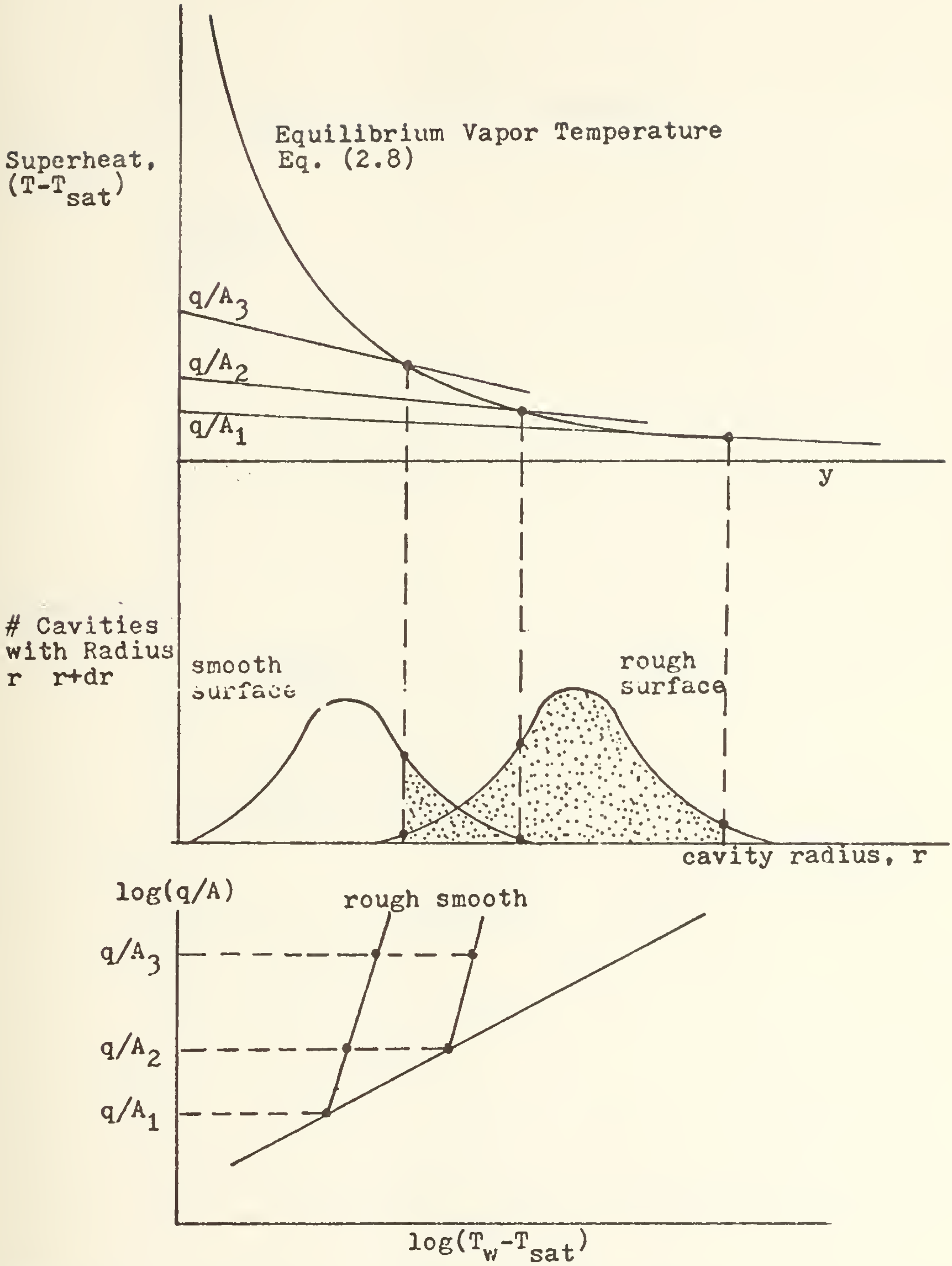

FIGURE 7 Comparison of Boiling Heat Transfer from Rough and Smooth Surfaces, Low h (21)

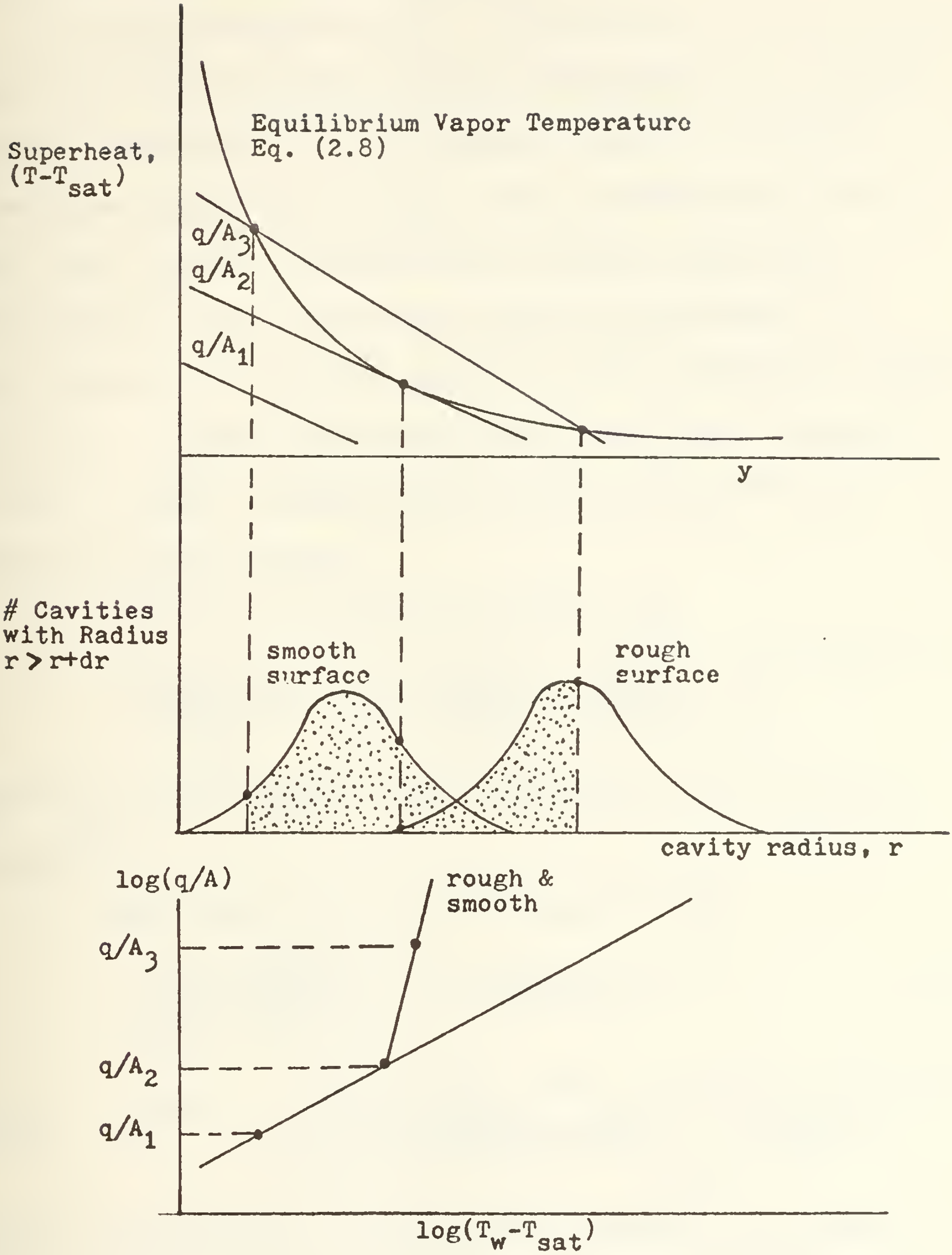

FIGURE 8 Comparison of Boiling Heat Transfer from Rough and Smooth Surfaces, High h (21)

2.4 Fully Developed Boiling Curve

In the previous section, the position of the boiling curve for forced convections was postulated to be essentially independent of the surface finish. In forced convection subcooled boiling, with a sufficiently high heat flux, the wall temperature becomes essentially independent of the convection effect (see Figure 9). This concept will also be applied to the two-phase forced convection region, and is the same equivalent approach as that of Chen. Three boiling correlations will be examined in this study:

1. Rohsenow boiling correlation (9)

$$\frac{C_{pl}\Delta T_{sat}}{h_{fg}} = C_{sf}\left(\frac{(q/A)_B}{\mu_l h_{fg}}\sqrt{\frac{g_o \sigma}{g(\rho_l-\rho_v)}}\right)^{0.33} Pr_l^{1.7} \qquad (2.20)$$

where C_{sf} is a constant for a particular fluid-surface combination.

2. Mikic pool boiling correlation (22)

$$\frac{(q/A)_B}{\mu_l h_{fg}}\sqrt{\frac{g_o \sigma}{g(\rho_l-\rho_v)}} = B_M(\phi\Delta T_{sat})^{m+1} \qquad (2.21)$$

where $$\phi^{m+1} = \frac{k_l^{1/2}\rho_l^{17/8}C_{pl}^{19/8}h_{fg}^{(m-23/8)}\rho_v^{(m-15/8)}}{\mu_l(\rho_l-\rho_v)^{9/8}\sigma^{(m-11/8)}T_{sat}^{(m-15/8)}}$$

B_M is a dimensional constant which depends on surface properties and gravity, and m is a constant which is a function of the cavity size distribution. For this analysis,

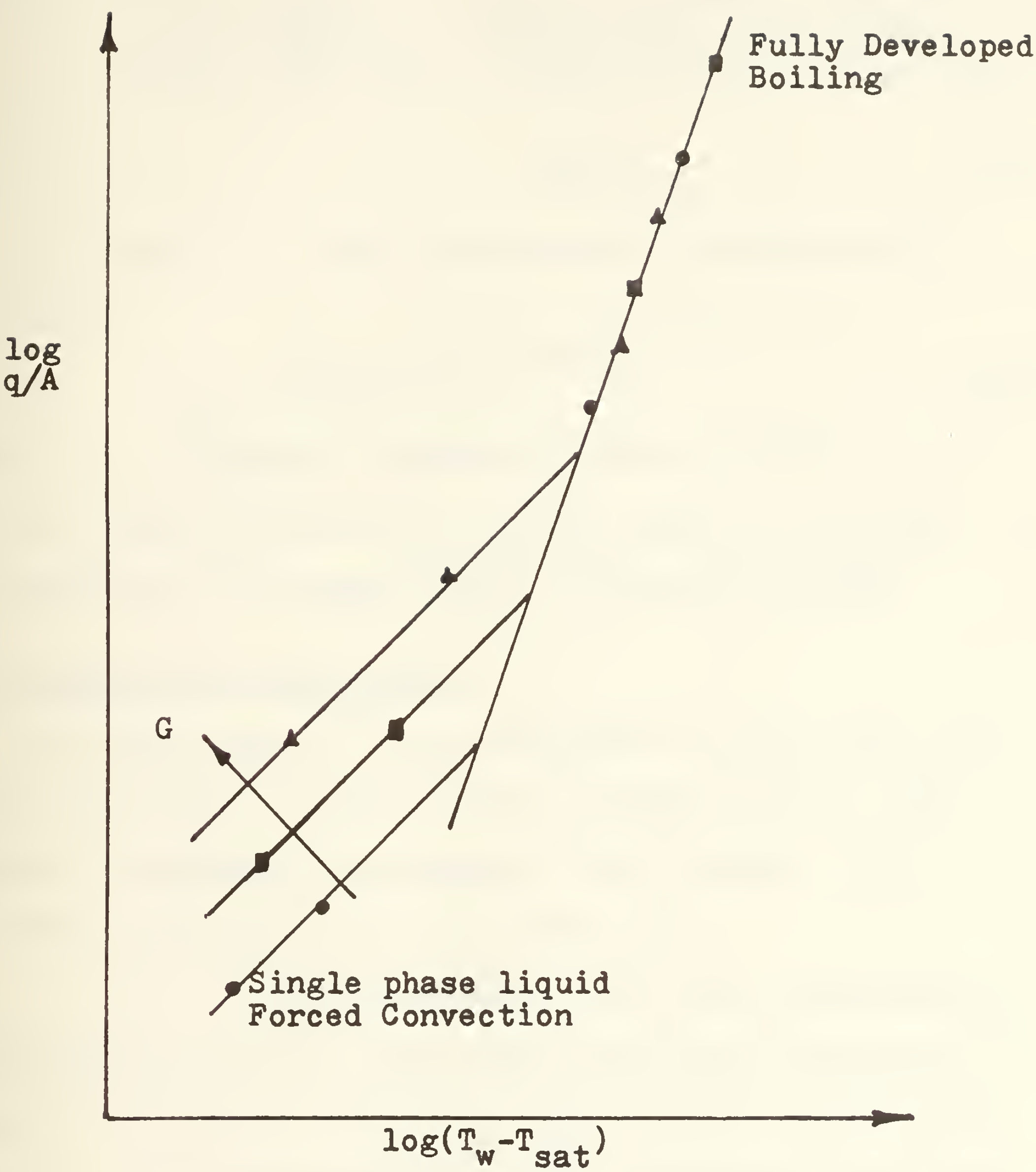

Figure 9 Typical Curve for Subcooled Boiling

m will be assumed equal to 2, in which case Equation (2.21) becomes:

$$\frac{(q/A)_B}{\mu_l h_{fg}}\sqrt{\frac{g_o \sigma}{g(\rho_l-\rho_v)}} = B_M \frac{k_l^{1/2}\rho_l^{17/8} C_{pl}^{19/8}\rho_v^{1/8}}{\mu_l h_{fg}^{7/8}(\rho_l-\rho_v)^{9/8}\sigma^{5/8} T_{sat}^{1/8}} \times (\Delta T_{sat})^3 \qquad (2.21)$$

3. Thom fully developed subcooled boiling correlation (23)

$$\Delta T_{sat} = W(q/A)_B^{0.5} e^{-P/1260} \qquad (2.22)$$

where W is a constant reported by Thom as 0.072

For each relation, the constant must be evaluated for the case of two-phase forced convection boiling.

2.5 Superposition Technique

The final part of the correlation is the method of adding the forced convection and nucleate boiling components to generate the complete heat transfer curve.

Two requirements for the curve are:

1. At wall superheats below that required for incipient boiling, the total heat transfer coefficient is equal to the forced convection heat transfer coefficient.

2. At sufficiently high superheats, the heat transfer coefficient approaches the fully developed boiling curve.

The procedure to be used in this analysis is to force the boiling component to be zero at the incipient boiling

point:

$$q/A = q/A_{FC} + q/A_B - q/A' \tag{2.23}$$

where q/A' is the heat flux on the fully developed boiling curve at the incipient wall superheat calculated from Equation (2.14) or (2.19).

If the fully developed curve has a slope of n on log-log coordinates, then:

$$q/A = q/A_{FC} + q/A_B\left(1 - \left(\frac{\Delta T_{sat,ib}}{\Delta T_{sat}}\right)^n\right) , \tag{2.24}$$

so that $1 - \left(\frac{\Delta T_{sat,ib}}{\Delta T_{sat}}\right)^n$ is a suppression factor for nucleate boiling. Figure 10 shows a sample plot of the superposition procedure.

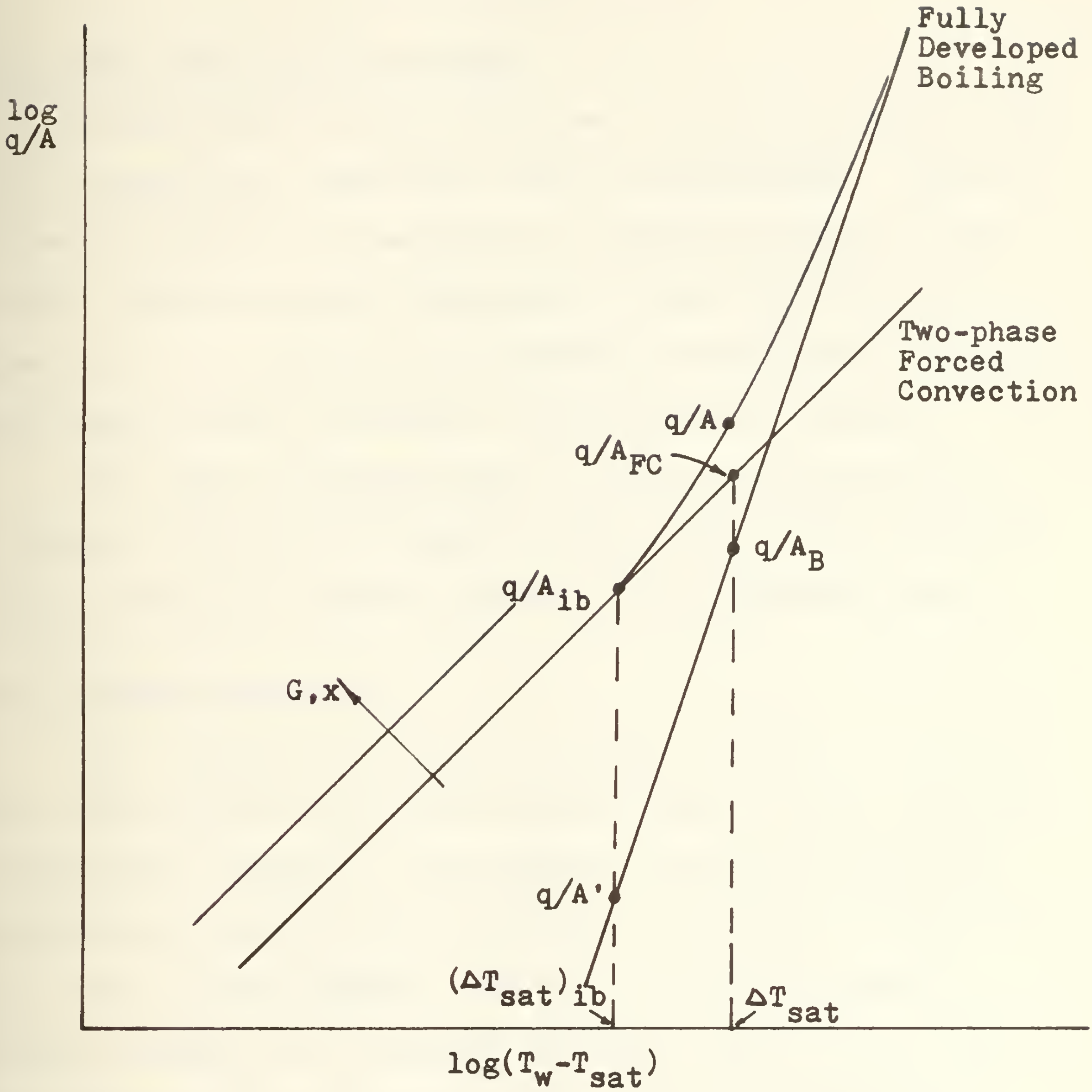

FIGURE 10 Superposition Technique

Chapter 3

CORRELATION OF DATA

3.1 Data Base and Properties

Eight sets of water data taken in round tubes were used as the basis for comparison with the correlation. Table 2 shows the range of experimental conditions covered by the data. 621 data points consisting of local conditions of mass flow rate, heat flux, saturation temperature, quality, and measured heat transfer coefficient were examined.

The water properties used in the calculations were linearly interpolated from the 1963 International Skeleton Steam Tables (24) after conversion to engineering units.

3.2 Forced Convection

The incipient nucleation criteria outlined in Section 2.3 was applied to each data point, with the heat transfer coefficient required in the analysis calculated from the unmodified Traviss forced convection correlation (Equation 2.1) as a first estimate. Equation (2.18) was used to first estimate the incipient heat flux based on the point of tangency, from which the size of the critical cavity radius was calculated from Equation (2.13). If this cavity was larger than the assumed maximum active cavity radius, the required heat flux to boil was calculated from:

Investigator	Ref	Flow	I.D. (in.)	$GX10^{-6}$ ($lbm/hr\text{-}ft^2$)	P (psia)	x %	$q/AX10^{-3}$ ($BTU/hr\text{-}ft^2$)
Dengler	(2)	up	1.0	.04-1.0	9-45	1-65	7-200
Schrock & Grossman Series A	(4)	up	0.116	0.9-2.2	52-176	1-49	100-628
Schrock & Grossman Series E	(5)	up	0.118	0.7-3.3	80-360	2-41	190-1450
Schrock & Grossman Series F	(5)	up	0.238	0.3-0.8	102-304	2-40	120-740
Bertoletti	(7)	up	0.197	0.8-2.9	926-1072	3-86	20-570
Sani	(3)	down	0.719	0.2-0.8	16-28	1-14	14-50
Wright Series 1	(6)	down	0.719	0.3-1.2	16-34	1-11	2-50
Wright Series 2	(6)	down	0.472	0.5-2.6	16-59	1-19	36-88

TABLE 2

Range of Conditions for Water Data Used in Testing Correlations

$$(q/A)_{ib} = \frac{\dfrac{Bk_l h_{FC}}{r^2_{max}}}{\dfrac{k_l}{r_{max}} - h_{FC}} \tag{3.1}$$

which is obtained by solving Equations (2.14) and (2.17) simultaneously with $r_{crit}=r_{max}$.

Several maximum cavity radii were tried; $r_{max}=10^{-5}$ ft. was found to give the best results, and was within the lmits previously described in Section 2.5. Figure 11 graphically displays this resulting nucleation criteria for water. The incipient heat flux may also be found by plotting the forced convection heat transfer component and reading off the value of heat flux or wall superheat at the intersection with the nucleation line of the correct pressure.

Those points with measured heat flux less than the incipient heat flux were classified as non-boiling, and plotted against the Traviss parameters:

$$\frac{NuF_2}{Re_l^{0.9}Pr_l} \quad \text{vs.} \quad X_{tt}$$

with $$Nu = \frac{h_{data}D}{k_l}$$

A curve of the same general form as the original Traviss $F(X_{tt})$ was then fit through the data; i.e.

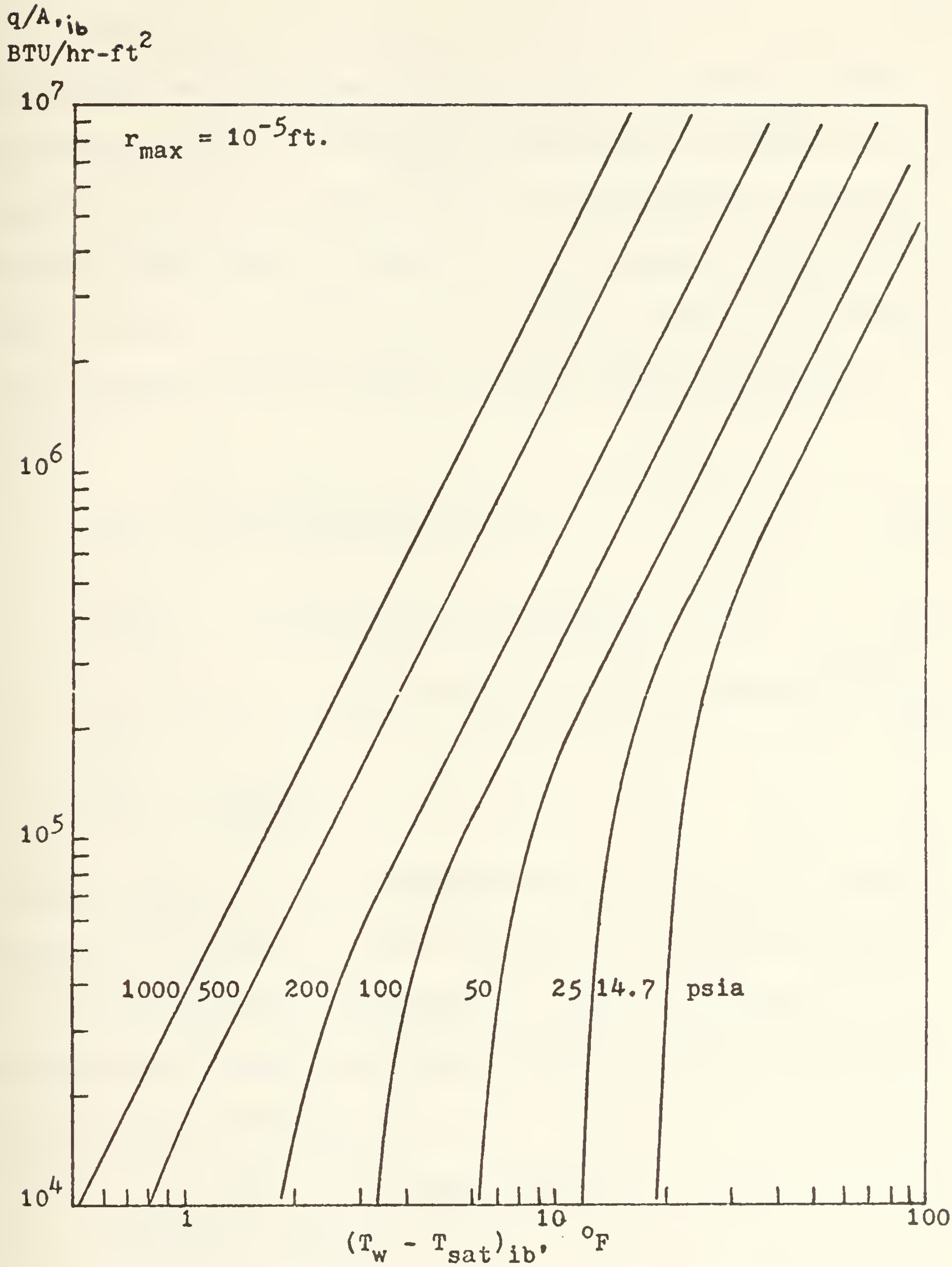

FIGURE 11 Incipient Nucleation Criteria for Water

$$F(X_{tt})_{try} = K_1(1/X_{tt} + K_2(1/X_{tt})^a) \qquad (3.2)$$

The procedure was repeated through three iterations with the new expressions for $F(X_{tt})_{try}$ inserted in Equation (2.1). It should be noted that the use of the proposed nucleation criteria at this stage is only as an indicator for possible boiling, and has no effect on the final equation for $F(X_{tt})$.

The proposed correlation for the forced convection component is:

$$h_{FC} = \frac{Re_1^{0.9} Pr_1 F(X_{tt})}{F_2} \frac{k_1}{D} \qquad (2.1)$$

$$F(X_{tt}) = 0.15(1/X_{tt} + 2.0(1/X_{tt})^{0.32}) \qquad (3.4)$$

$$F_2 = 5Pr_1 + 5\ln(1+5Pr_1) + 2.5\ln(0.00313Re_1^{0.812}) \qquad (2.4)$$

$$Re_1 = \frac{GD(1-x)}{\mu_1}$$

This correlation is compared with the original Traviss correlation in Figure 12, and the fit of the non-boiling data to the proposed correlation is shown in Figure 13. The same non-boiling points were plotted against the Chen macroconvective parameters,

$$\frac{Nu}{0.023Re_1^{0.8}Pr_1^{0.4}} \quad \text{vs.} \quad 1/X_{tt}$$

and are shown in Figure 14. The two correlations were compared by computing the average deviation between the predicted and experimental values of the forced convection

parameters.

For the Hall-Traviss correlation,

$$\text{Deviation} = \frac{(F(X_{tt}))_{pred} - (F(X_{tt}))_{data}}{(F(X_{tt}))_{data}}$$

For the Chen correlation,

$$\text{Deviation} = \frac{F_{pred} - F_{data}}{F_{data}}$$

The results of this comparison are summarized in Table 3, and shows that the proposed forced convection correlation is generally superior to the Chen macroconvective correlation, when applied to data for which there is no nucleation. It should be noted that the Chen method requires the superposition of both a forced convection and nucleate boiling component, and that for the typical range of interest, the nucleate boiling component is never completely suppressed (see Figure 4).

3.3 Nucleate Boiling

For those data points where the applied heat flux was higher than the incipient flux, enhanced heat transfer due to nucleate boiling was assumed to take place. This effect can be determined by rearranging Equation (2.24):

$$q/A_B = \frac{(q/A_{data} - q/A_{FC})}{1 - \left(\frac{\Delta T_{sat,ib}}{\Delta T_{sat,data}}\right)^n} \tag{3.5}$$

and $$\Delta T_{sat,data} = \frac{q/A_{data}}{h_{data}}$$

Knowing the residual heat transferred by nucleation and the corresponding wall superheat, the appropriate value of C_{sf}, B_M, or W (Equations (2.20), (2.21), (2.22)) can be calculated for a particular data point. Following the argument for the effect of surface finish on forced convection boiling, a single point should establish the position of the boiling curve. In reality, the large scatter present in the prediction of incipient boiling and nucleate boiling phenomena led to a graphical approach to obtain a "best" value of the particular constant. In this respect, a value judgment was made by weighting those data points where significant boiling should exist (low G, low x, high q/A). The best values obtained for the boiling constants were:

$$C_{sf} = 0.0288$$

$$B_M = 0.0000213$$

$$W = 0.132$$

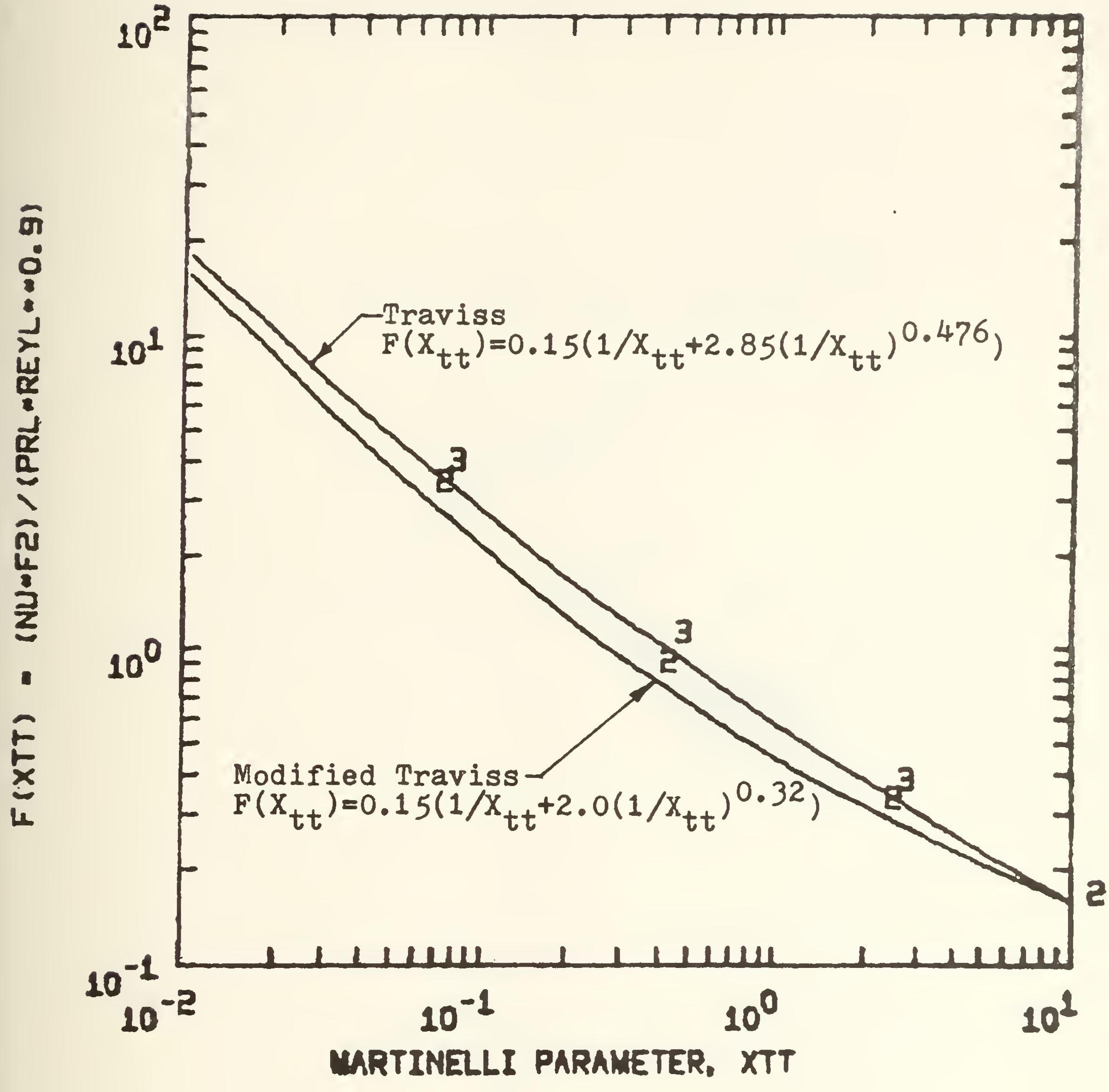

FIGURE 12 Comparison of Traviss (17) Forced Convection Correlation and Proposed Forced Convection Correlation

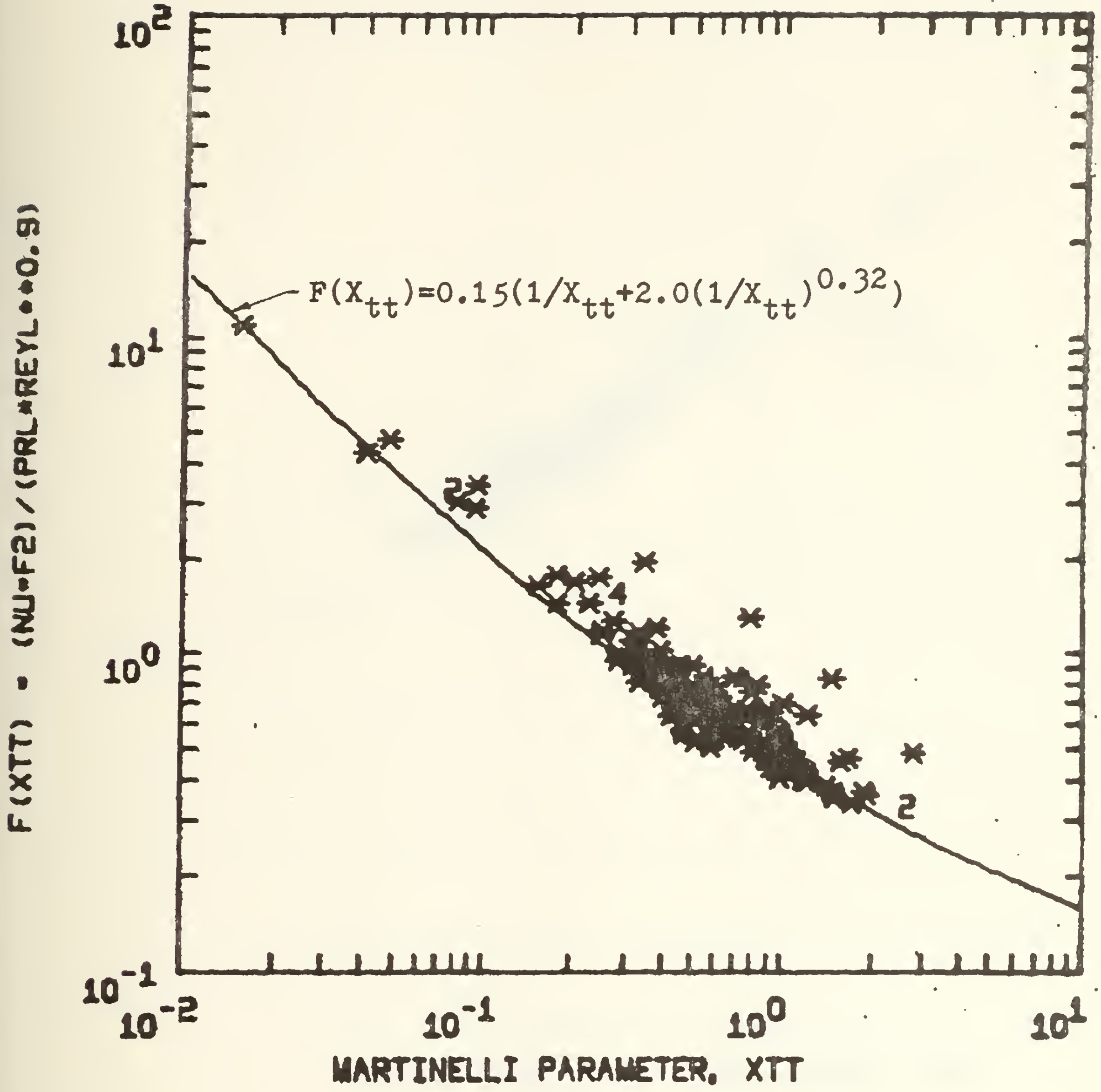

FIGURE 13 Comparison of Proposed Forced Convection Correlation with Non-Boiling Data

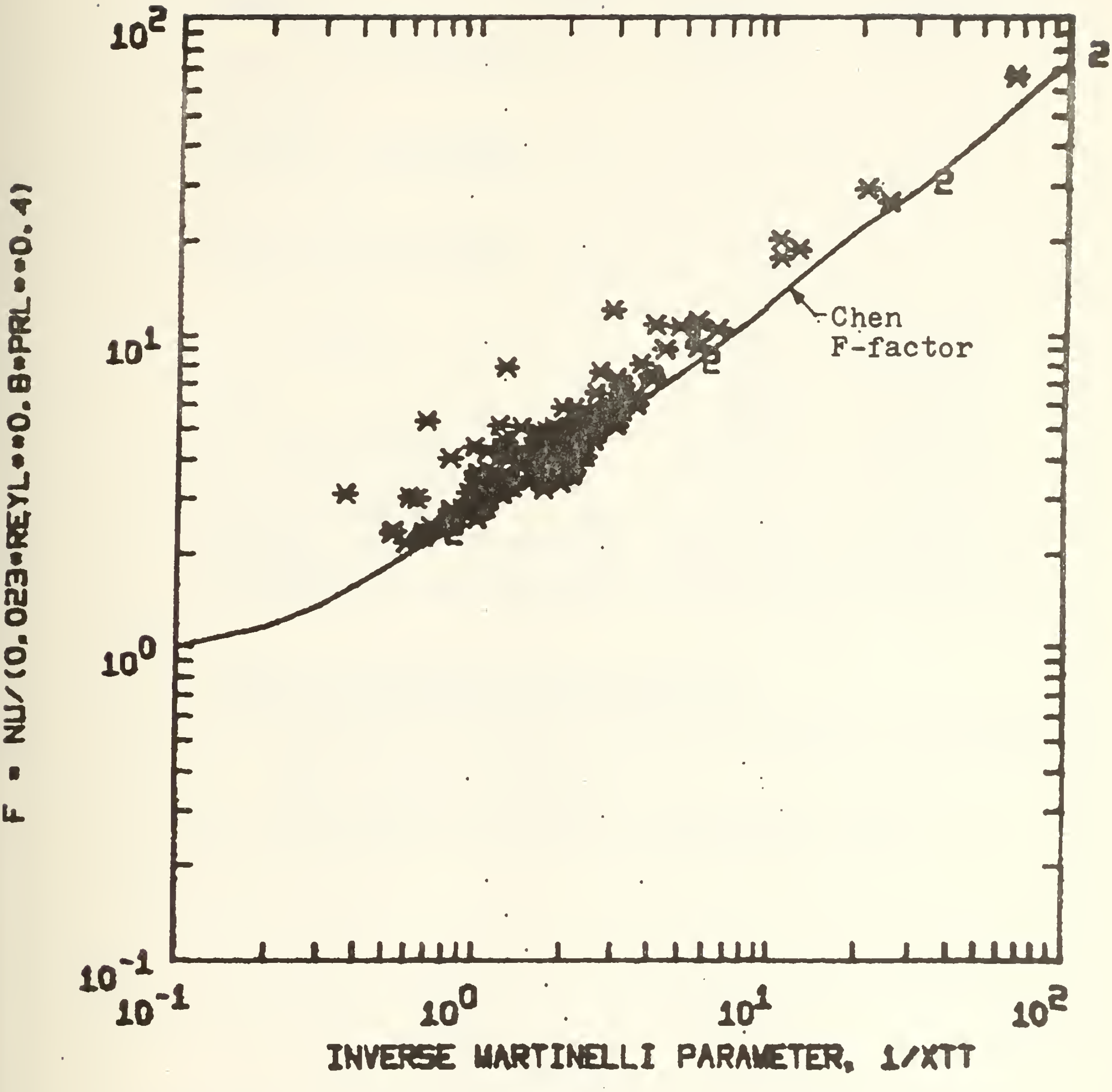

FIGURE 14 Comparison of Chen (8) Forced Convection Correlation with Non-Boiling Data

Data	# Non-Boiling Points	Average Deviations for A	B
Dengler	25	0.2677	0.3626
Schrock & Grossman Series A	9	0.1310	0.1531
Schrock & Grossman Series E	0	-	-
Schrock & Grossman Series F	0	-	-
Bertoletti	1	0.5514	0.5238
Sani	83	0.0886	0.1252
Wright Series 1	67	0.0895	0.1188
Wright Series 2	29	0.1867	0.1772
Average	214	0.1270	0.1610

<u>Forced Convection Correlations</u>

A - Modified Traviss Forced Convection (Equations 2.1, 3.4 2.4, 2.2)

B - Chen Macroconvective (Equation 1.9)

TABLE 3

Comparison of Forced Convection Correlations with Non-Boiling Data Predicted by Proposed Incipient Boiling Criteria

Chapter 4

RESULTS OF THE ANALYSIS

With all four components of the correlation complete, it was tested against the data. This method may assume either the wall superheat or the heat flux specified. Since a specified heat flux is the more usual design case, the data was reduced using this assumption, entailing an iterative procedure to determine the wall temperature resulting from the experimental heat flux. Sample calculations for both approaches are provided in Appendix II. Due to the large number of data points examined, a digital computer was employed, but the predicted heat transfer coefficients are readily hand calculated. A listing and sample output from the data reduction program are provided in Appendix IV.

The criteria chosen for comparison between predicted and experimental results is the deviation, or difference ratio.

For the case of specified wall superheat:

$$\text{Deviation} = \frac{(h_{pred} - h_{data})}{h_{data}}$$

For the case of specified heat flux:

$$\text{Deviation} = \frac{(\Delta T_{sat,pred} - \Delta T_{sat,data})}{\Delta T_{sat,data}}$$

The results were produced in two forms. The first is scatter plots of predicted heat transfer coefficient vs. the experimental value (see Appendix III). Points lying on the 45 degree line represent perfect correlation. The scatter plots show that for the most part, the data is roughly centered about the 45 degree line. The anomolous points well off the experimental values can be found on each plot, and are possibly bad data.

The second presentation of results is a tabular summary of the computed average absolute value deviation (see Table 4), The proposed method of correlation compares very favorably with the results from the widely accepted Chen method, and in fact, the Hall-Traviss forced convection/ Mikic nucleate boiling had the lowest combined average deviation of ±15.4%. Each of the three proposed correlations, using the methods outlined in Chapters 2 and 3, was able to predict heat transfer coefficients over a wide range of conditions with an average deviation less than ±30% for any particular data set.

Data Set	# Points	Average Deviations for Correlations I	II	III	IV
Dengler	119	0.2036	0.2495	0.1619	0.1595
Schrock & Grossman Series A	160	0.2096	0.2034	0.2302	0.1902
Schrock & Grossman Series E	50	0.1692	0.1704	0.1886	0.1637
Schrock & Grossman Series F	38	0.2179	0.1442	0.2856	0.1546
Bertoletti et al	64	0.2009	0.1845	0.2013	0.1842
Sani	84	0.0947	0.0879	0.0875	0.0876
Wright #1	67	0.0938	0.0895	0.0895	0.0895
Wright #2	39	0.1638	0.1772	0.1827	0.1812
Average	621	0.1739	0.1744	0.1767	0.1541

Correlations

I Chen Correlation

II Hall-Traviss Forced Convection with Rohsenow Nucleate Boiling, C_{sf}=0.0288, r_{max}=0.00001 ft.

III Hall-Traviss Forced Convection with Thom Nucleate Boiling, W=0.132, r_{max}=0.00001 ft.

IV Hall-Traviss Forced Convection with Mikic Nucleate Boiling, B_M=0.0000213, r_{max}=0.00001 ft.

TABLE 2

Summary of Results

Chapter 5

SUMMARY AND CONCLUSIONS

The case of forced convection boiling of saturated water was treated in this study with the hope of developing a method of correlating local heat transfer coefficients based on physical principals. The total heat transfer mechanism was postulated to be made up of a forced convection effect and a nucleate boiling effect where it exists.

For annular flow, which exists over much of the quality range for low and moderate pressure, the forced convection component is due to the convective transport through a highly turbulent liquid film. A modified Traviss (17) analysis based on the momentum-heat transfer analogy, using the universal velocity profile to describe the annular liquid film was used. The simplified design equations proposed by Traviss were corrected to fit non-boiling data. The incipient nucleation criteria proposed by Bergles and Rohsenow (19) based on vapor bubble equilibrium in a linear temperature profile near the wall was employed to account for the effect of forced convection on the onset of boiling. A maximum active cavity radius of 10^{-5}ft. was suggested. Boiling was assumed to exist only if the applied heat flux was greater than the incipient boiling heat flux.

The proposed forced convection correlation was found to fit the non-boiling data identified by the incipient nucleation criteria better than the Chen (8) macroconvective relation.

The nucleate boiling and forced convection components were superposed by forcing the boiling heat flux to be zero at the point of incipient nucleation. The position of the fully developed boiling curve was argued to be essentially independent of surface finish using the same reasoning as Brown (21). The nucleate boiling correlations of Rohsenow, Mikic, and Thom were each tried as the representative component to be added to the modified Traviss forced convection component.

The proposed method was used to predict heat transfer coefficients for eight sets of water data, assuming the heat flux as the specified independent variable. The widely recommended Chen correlation was also applied to the same data. The proposed method produced results which compared very favorably with the local values predicted by the Chen method. The Hall-Traviss forced convection/Mikic nucleate boiling had the lowest combined average deviation of all correlations tested ($\pm 15.4\%$), while the Chen method produced a combined average deviation of $\pm 17.4\%$. The results were found to be relatively insensitive to the particular boiling correlation selected.

The proposed method has the advantage of not requiring the use of purely empirical and graphically presented correlation factors, and is recommended for predicting forced convection boiling heat transfer coefficients for water at less than 1000 psia, in the approximate quality range of 1-70%.

Although the same mechanisms of heat transfer should apply to other fluids, the coefficients in the equations for forced convection and boiling should be verified before general use.

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Appendix I

PROPERTIES OF SATURATED WATER

KEY

1-SATURATION TEMPERATURE, DEG FAHR
2-SATURATION PRESSURE, PSIA
3-LIQUID DENSITY, LBM/FT**3
4-VAPOR DENSITY, LBM/FT**3
5-LATENT HEAT OF VAPORIZATION, BTU/LBM
6-LIQUID SPECIFIC HEAT, BTU/LBM-DEGF
7-LIQUID SURFACE TENSION, LBF/FT
8-LIQUID VISCOSITY, LBM/HR-FT
9-VAPOR VISCOSITY, LBM/HR-FT
10-LIQUID THERMAL CONDUCTIVITY, BTU/HR-FT-DEGF
11-LIQUID PRANDTL NUMBER

TSAT 1	PSAT 2	RHOL 3	RHOV 4	HFG 5	CPL 6	SIGMA 7	MUL 8	MUV 9	KL 10	PRL 11
170.	6.1	60.79	0.016	995.9	1.00	0.0043	0.900	0.0270	0.386	2.340
180.	7.6	60.58	0.020	990.0	1.00	0.0043	0.838	0.0275	0.388	2.170
190.	9.4	60.36	0.025	984.0	1.00	0.0042	0.785	0.0280	0.390	2.020
200.	11.7	60.12	0.030	977.8	1.01	0.0041	0.737	0.0285	0.391	1.890
210.	14.2	59.88	0.036	971.6	1.01	0.0040	0.694	0.0291	0.393	1.773
220.	17.4	59.63	0.044	965.1	1.01	0.0040	0.654	0.0296	0.394	1.674
230.	20.8	59.37	0.052	958.6	1.01	0.0039	0.616	0.0301	0.395	1.580
240.	25.2	59.10	0.062	952.1	1.01	0.0038	0.584	0.0306	0.396	1.497
250.	29.9	58.82	0.073	945.5	1.01	0.0037	0.553	0.0311	0.397	1.417
260.	35.7	58.53	0.086	938.7	1.02	0.0037	0.526	0.0316	0.397	1.350
270.	42.1	58.24	0.100	931.8	1.02	0.0036	0.501	0.0321	0.397	1.288
280.	49.5	57.94	0.116	924.9	1.02	0.0035	0.479	0.0326	0.397	1.232
290.	55.0	57.63	0.135	917.9	1.02	0.0034	0.458	0.0331	0.397	1.183
300.	59.2	57.31	0.155	910.7	1.03	0.0034	0.439	0.0336	0.397	1.139
310.	73.2	56.98	0.179	903.1	1.03	0.0033	0.422	0.0341	0.396	1.099
320.	89.6	56.65	0.203	895.3	1.03	0.0032	0.406	0.0346	0.395	1.060
330.	103.7	56.30	0.233	887.6	1.04	0.0031	0.392	0.0351	0.394	1.032
340.	118.3	55.95	0.265	879.7	1.04	0.0030	0.378	0.0356	0.393	1.005
350.	135.2	55.59	0.300	871.3	1.05	0.0029	0.366	0.0360	0.392	0.981
360.	153.5	55.22	0.339	862.8	1.05	0.0029	0.355	0.0365	0.390	0.959

TSAT 1	PSAT 2	RHOL 3	RHOV 4	HFG 5	CPL 6	SIGMA 7	MUL 8	MUV 9	KL 10	PRL 11
370.	173.7	54.84	0.382	854.1	1.06	0.0028	0.345	0.0370	0.388	0.940
380.	196.4	54.45	0.430	845.2	1.07	0.0027	0.335	0.0375	0.386	0.923
390.	220.7	54.06	0.481	836.2	1.07	0.0026	0.326	0.0379	0.384	0.909
400.	248.3	53.65	0.539	826.6	1.08	0.0025	0.317	0.0384	0.382	0.897
410.	276.7	53.24	0.599	817.0	1.09	0.0024	0.309	0.0389	0.379	0.886
420.	309.9	52.81	0.669	807.0	1.10	0.0023	0.302	0.0393	0.377	0.878
430.	344.2	52.37	0.742	796.8	1.10	0.0023	0.295	0.0398	0.374	0.870
440.	382.7	51.92	0.824	785.9	1.11	0.0022	0.288	0.0403	0.371	0.864
450.	423.5	51.46	0.912	774.8	1.12	0.0021	0.282	0.0408	0.368	0.859
460.	467.9	50.98	1.008	763.5	1.13	0.0020	0.276	0.0413	0.364	0.852
470.	516.0	50.49	1.113	751.8	1.15	0.0019	0.270	0.0418	0.360	0.853
480.	566.8	50.00	1.225	739.8	1.16	0.0018	0.264	0.0423	0.357	0.858
490.	623.1	49.47	1.351	727.1	1.17	0.0017	0.259	0.0428	0.353	0.862
500.	680.8	48.95	1.481	714.1	1.19	0.0016	0.253	0.0433	0.349	0.866
510.	746.2	48.39	1.633	700.7	1.21	0.0015	0.249	0.0438	0.344	0.875
520.	813.2	47.82	1.789	687.0	1.23	0.0015	0.244	0.0444	0.339	0.884
530.	886.8	47.22	1.966	672.3	1.25	0.0014	0.239	0.0450	0.334	0.895
540.	964.1	46.61	2.155	657.1	1.28	0.0013	0.234	0.0456	0.330	0.909
550.	1046.7	45.97	2.362	641.0	1.31	0.0012	0.229	0.0462	0.324	0.925
560.	1135.2	45.31	2.591	624.3	1.34	0.0011	0.225	0.0469	0.319	0.945

APPENDIX II

Sample Calculations

Sample 1 - $(T_w - T_{sat})$ is specified

Given:

$D = 1.0$ in

$\dot{m} = 2900$ lbm/hr

$\Delta T_{sat} = 17.9\ ^{o}F$

$h_{data} = 5530$ BTU/hr-ft^2

$x = 0.074$

$T_{sat} = 255\ ^{o}F$

$P_{sat} = 33$ psia

Properties:

$\rho_l = 58.4$ lbm/ft^3

$\rho_v = 0.080$ lbm/ft^3

$h_{fg} = 941.7$ BTU/lbm

$\mu_l = 0.54$ lbm/hr-ft

$\mu_v = 0.031$ lbm/hr-ft

$c_{pl} = 1.02$ BTU/lbm-^{o}F

$Pr_l = 1.38$

$k_l = 0.397$ BTU/hr-ft-^{o}F

$\sigma = 0.0037$ lb/ft

I. Forced convection heat transfer coefficient

Hall-Traviss

Calculate $X_{tt} = \frac{1-x}{x}^{0.9}\left(\frac{\mu_l}{\mu_v}\right)^{0.1}\left(\frac{\rho_v}{\rho_l}\right)^{0.5}$

$$= \left(\frac{1-0.074}{0.074}\right)^{0.9}\left(\frac{0.080}{58.4}\right)^{0.5}\left(\frac{0.54}{0.031}\right)^{0.1}$$

$$= 0.474$$

$$G = \frac{\dot{m}}{A} = \frac{2900}{0.0055} = 531700 \text{ lbm/hr-ft}^2$$

$$F(X_{tt}) = 0.15(\ 1/X_{tt} + 2.0(1/X_{tt})^{0.32})$$

$$= 0.697$$

$$F_2 = 5Pr_l + 5\ln(1+5Pr_l) + 2.5\ln(0.00313Re_l^{0.812})$$

$$Re_l = \frac{GD(1-x)}{\mu_l} = \frac{(531700)(1)(0.926)}{(0.54)(12)} = 76000$$

$$F_2 = 5(1.38) + 5\ln(1+5(1.38)) + 2.5\ln(0.00313(76000)^{0.812})$$

$$F_2 = 25.63$$

$$h_{FC} = \frac{Re_l^{0.9}F(X_{tt})Pr_l}{F_2}\ \frac{k_l}{D}$$

$$= \frac{(76000)^{0.9}(0.697)(1.38)}{25.63}\ \frac{0.397(12)}{1}$$

$$= 4426 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F}$$

Chen Forced Convection

$$1/X_{tt} = 2.11$$

$F = 4.5$ (Figure 3)

$$h_{mac} = 0.023\ Re_l^{0.8} Pr_l^{0.4} \frac{k_l}{D} F$$

$$= 0.023(76000)^{0.8}(1.38)^{0.4}\frac{(0.397)(12)}{1}(4.5)$$

$$= 4500\ \text{BTU/hr-ft}^2\text{-}^\circ\text{F}$$

II. Incipient Boiling Point

Calculate

$$B = \frac{2\sigma T_{sat} v_{fg}}{h_{fg}} = \frac{(2)(0.0037)(255+460)(12.48)}{(941.7)(778)}$$

$$= 9.01X10^{-5}\ \text{ft}^\circ\text{R}$$

$$(\Delta T_{sat})_{ib} = \frac{4Bh_{FC}}{h_{fg}} = \frac{(4)(9.01X10^{-5})(4426)}{0.397}$$

$$= 4.0\ ^\circ\text{R} \quad \text{(based on tangency point)}$$

$$r_{crit} = \sqrt{\frac{Bk_l}{(q/A)_{ib}}}$$

$$(q/A)_{ib} = h_{FC}(\ T_{sat})_{ib} = (4426)(4.0) = 17700$$

$$r_{crit} = \sqrt{\frac{(9.01X10^{-5})(0.397)}{17700}} = 4.5X10^{-5}\ \text{ft.}$$

r_{crit} is greater than r_{max}, so $r_{crit}=r_{max}$

$r_{max} = 10^{-5}$ ft.

$$(\Delta T_{sat})_{ib} = \frac{\dfrac{k_l}{r_{max}^2}}{\dfrac{k_l}{r_{max}} - h_{FC}} = 10.1\ ^\circ\text{F}$$

III. Boiling Heat Transfer Coefficients

<u>Chen</u>

$$Re_l F^{1.25} = (76000)(4.5)^{1.25} = 5.0X10^5$$

$S = 0.1$ (Figure 4)

$$h_{mic} = 0.00122 \frac{k_l^{0.79} cp_l^{0.45} \rho_l^{0.49} g_o^{0.25}}{\sigma^{0.5} \mu_l^{0.24} h_{fg}^{0.24} \rho_v^{0.24}}$$

$$X \; \Delta T_{sat}^{0.24} \Delta P_{sat}^{0.75} S$$

$$\Delta P_{sat} = \frac{h_{fg}}{T_{sat} v_{fg}} \Delta T_{sat} \quad \text{(Clausius-Clapeyron)}$$

$$h_{mic} = \frac{0.00122(0.397)^{0.79}(1.02)^{0.45}(58.4)^{0.49}}{(0.0037)^{0.5}(0.54)^{0.24}(941.7)^{0.24}}$$

$$X \; \frac{(4.173X10^8)^{0.25}}{(0.080)^{0.24}} \Delta T_{sat}^{0.24} \Delta P_{sat}^{0.75} S$$

$$\Delta P_{sat} = \frac{h_{fg} \Delta T_{sat}}{T_{sat} v_{fg}} = \frac{(941.7)(778)}{(710)(12.48)} \Delta T_{sat}$$

$$\Delta P_{sat} = 82.11 \, \Delta T_{sat}$$

$$\Delta P_{sat}^{0.75} = 27.28 \, \Delta T_{sat}^{0.75}$$

$$h_{mic} = 11.36 \, \Delta T_{sat}^{0.99} = 11.36(17.9)^{0.99}$$

$$h_{mic} = 198 \text{ BTU/hr-ft}^2\text{-}^oF$$

<u>Thom Nucleate Boiling</u> will be used to demonstrate proposed method of correlation

$$q/A_{pred} = q/A_{FC} + q/A_B\left(1 - \left(\frac{\Delta T_{sat,ib}}{\Delta T_{sat}}\right)^n\right)$$

n = 2 for Thom correlation

$$q/A_B = \left(\frac{\Delta T_{sat} e^{P/1260}}{W}\right)^2 \qquad (W = 0.132)$$

$$= \left(\frac{(17.9)(e^{33/1260})}{0.132}\right)^2 = 19378 \text{ BTU/hr-ft}^2$$

$$q/A_B\left(1 - \left(\frac{\Delta T_{sat,ib}}{\Delta T_{sat}}\right)^2\right) = 19378\left(1 - \left(\frac{10.1}{17.9}\right)^2\right)$$

$$= 13209 \text{ BTU/hr-ft}^2$$

$$h_B = \frac{q/A_B}{\Delta T_{sat}} = \frac{13209}{17.9} = 738 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F}$$

IV. Total Heat Transfer Coefficients and Deviations

Chen

$$h = h_{mac} + h_{mic} = 4500 + 198 = 4698 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F}$$

$$\text{Deviation} = \frac{h_{pred} - h_{data}}{h_{data}} = \frac{4698-5530}{5530}$$

$$= -0.15$$

Hall-Traviss/Thom

$$h = h_{FC} + h_B = 4426 + 738 = 5164 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F}$$

$$\text{Deviation} = \frac{5164-5530}{5530} = -0.067$$

Sample 2 - q/A is specified

Given:

Identical conditions as Sample 1, with exception that $q/A_{data} = 99000$ BTU/hr-ft^2, and the wall superheat must be predicted.

I. Forced Convection Heat Transfer Coefficient

Chen $\qquad h_{mac} = 4500$ BTU/hr-ft^2-^oF

Hall-Traviss $\qquad h_{FC} = 4426$ BTU/hr-ft^2-^oF

II. Incipient Boiling Point (not applicable to Chen method)

$$q/A_{ib} = 44700 \text{ BTU/hr-ft}^2$$

$$(\Delta T_{sat})_{ib} = 10.1 \ ^oF$$

III. Boiling Heat Transfer Coefficients and Deviations

Chen

$$\text{Let } (\Delta T_{sat})_{try} = \frac{q/A_{data}}{h_{mac}} = 22 \ ^oF$$

$$(h_{mic})_{try} = 11.36(\Delta T_{sat})_{try}^{0.99} = 11.36(22)^{0.99}$$

$$= 242$$

$$h_{try} = 4500 + 242 = 4742$$

$$(\Delta T_{sat}) = \frac{q/A_{data}}{h_{try}} = \frac{99000}{22} = 20.9 \ ^oF$$

$$\text{Now let } (\Delta T_{sat})_{try} = 20.9 \ ^oF$$

$$(h_{mic})_{try} = 11.36(20.9)^{0.99} = 230$$

$$h_{try} = 4500 + 230 = 4730 \text{ BTU/hr-ft}^2\text{-}^{o}\text{F}$$

$$(\Delta T_{sat})_{try} = \frac{99000}{4730} = 20.9 \ ^{o}\text{F}$$

Assume the trial and error solution has converged to the values

$$\Delta T_{sat} = 20.9 \ ^{o}\text{F}$$

$$h = 4730 \text{ BTU/hr-ft}^2\text{-}^{o}\text{F}$$

$$\text{Deviation} = \frac{(\Delta T_{sat})_{pred} - (\Delta T_{sat})_{data}}{(\Delta T_{sat})_{data}}$$

$$= \frac{20.9 - 17.9}{17.9} = 0.168$$

<u>Hall-Traviss Forced Convection/Thom Boiling</u>

$$q/A_B = \left(\frac{e^{33/1260\,\Delta T_{sat}}}{0.132}\right)^2 = 60.47\,\Delta T_{sat}^{\ 2}$$

$$\text{Let } (\Delta T_{sat})_{try} = \frac{q/A_{data}}{h_{FC}} = \frac{99000}{4426} = 22.4 \ ^{o}\text{F}$$

$$q/A_B(1 - \left(\frac{\Delta T_{sat,ib}}{\Delta T_{sat}}\right)^2) = (60.47)(22.4)^2(1-\left(\frac{10.1}{22.4}\right)^2)$$

$$= 24200 \text{ BTU/hr-ft}^2$$

$$h_B = \frac{q/A_B}{(\Delta T_{sat})_{try}} = \frac{24200}{22.4} = 1080$$

$$h = h_{FC} + h_B = 4426 + 1080 = 5506$$

$$(\Delta T_{sat})_{try} = \frac{q/A_{data}}{h} = \frac{99000}{5506} = 18.0 \ ^{o}\text{F}$$

$$\text{Let } (\Delta T_{sat})_{try} = 18.0 \ ^{o}\text{F}$$

Following the above procedure, the solution will converge in four iterations to the values:

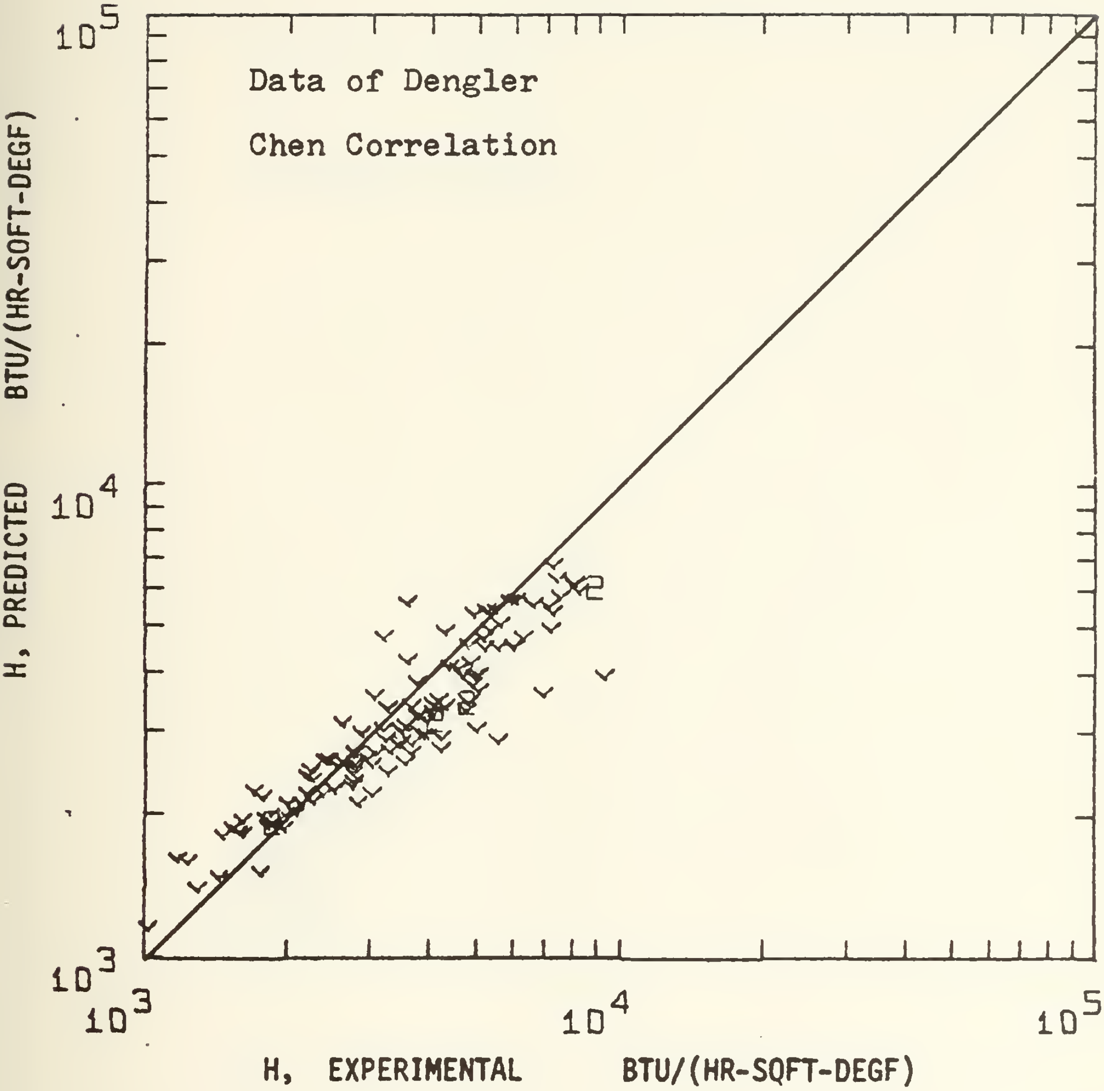
$(\Delta T_{sat})_{try} = 18.9\ ^{o}F$

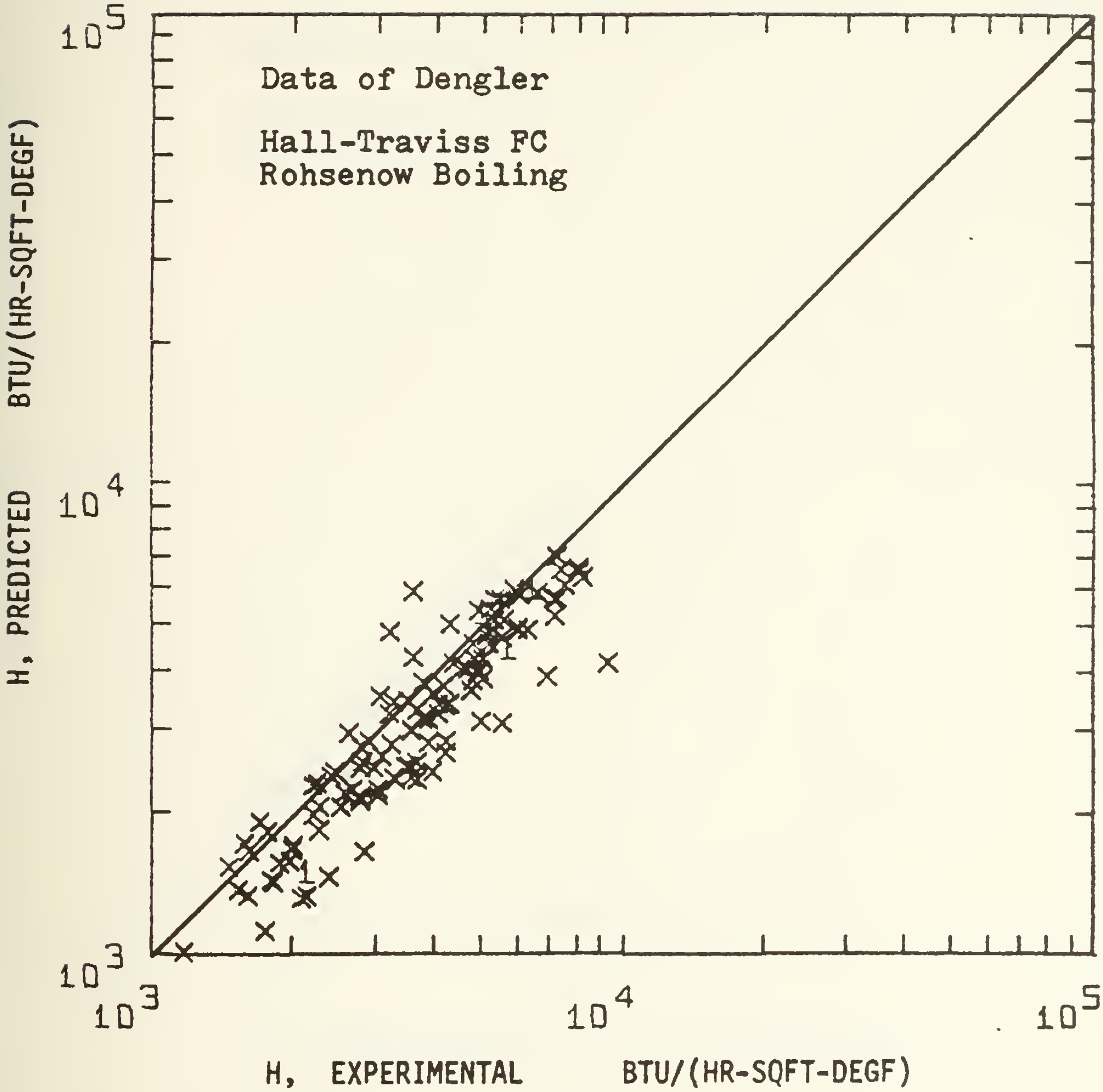
$h = 5243\ BTU/hr\text{-}ft^2\text{-}^{o}F$

$$\text{Deviation} = \frac{18.9 - 17.9}{17.9} = 0.056$$

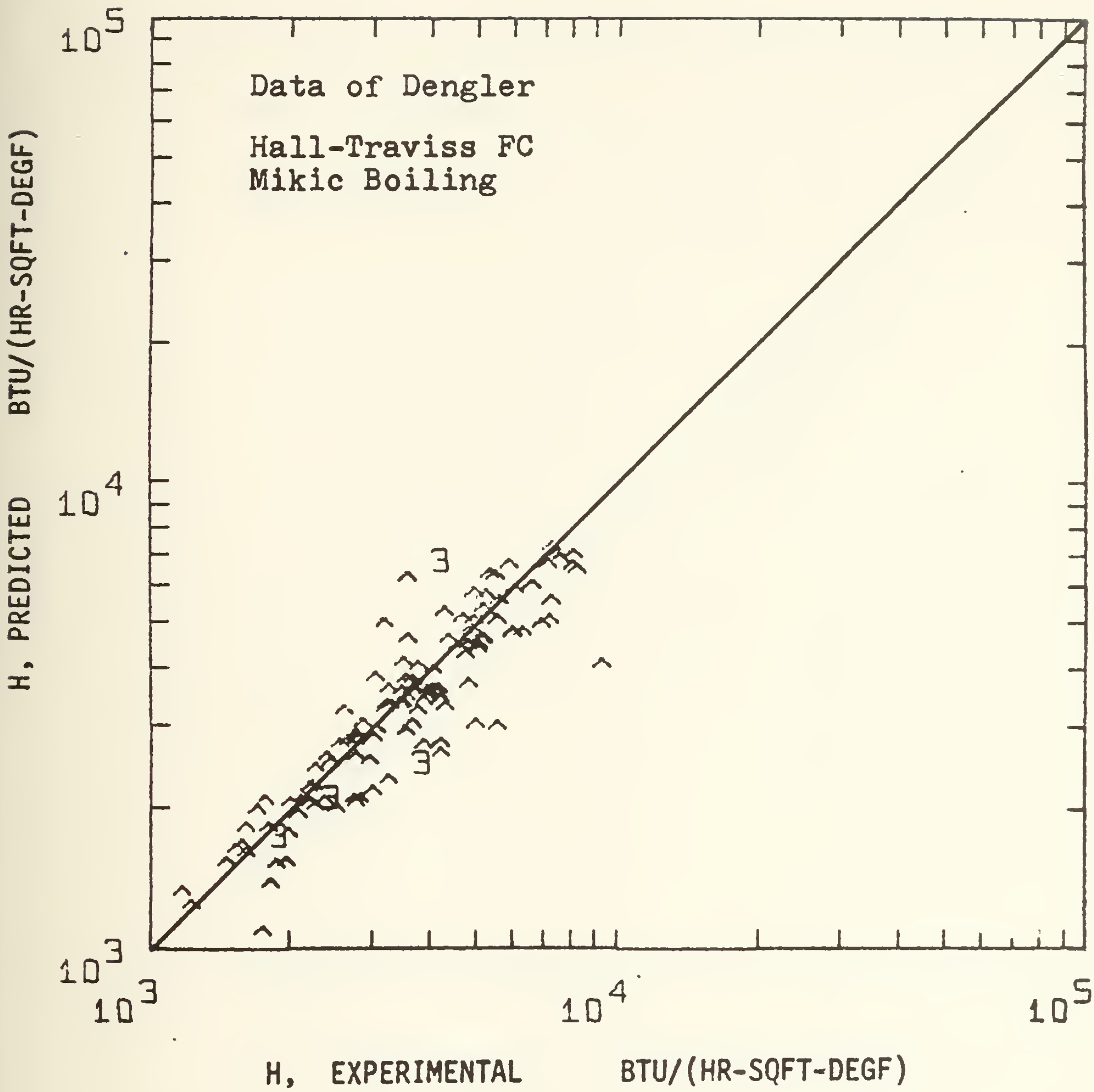
Appendix III

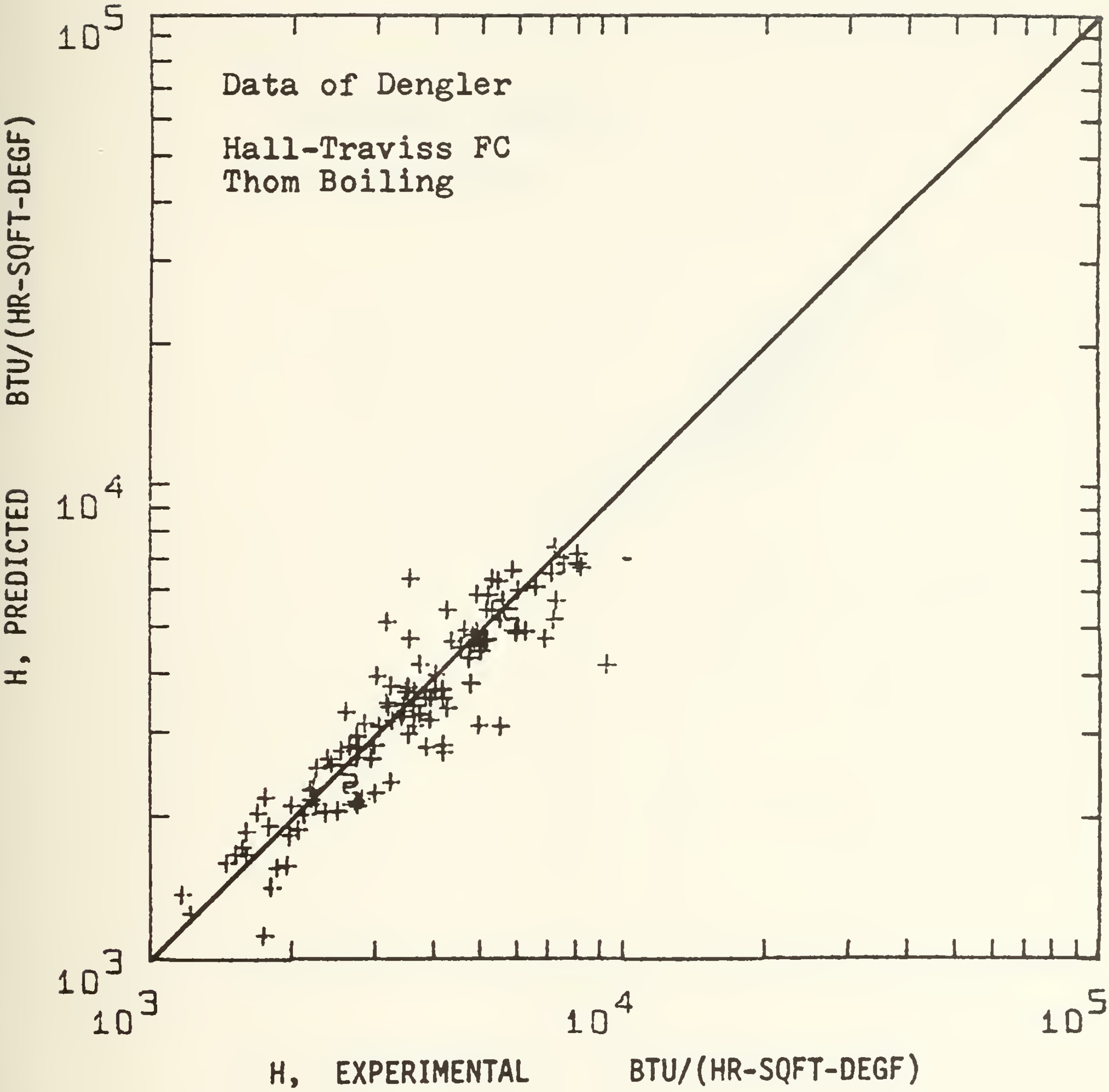
GRAPHICAL COMPARISON OF CORRELATIONS WITH DATA

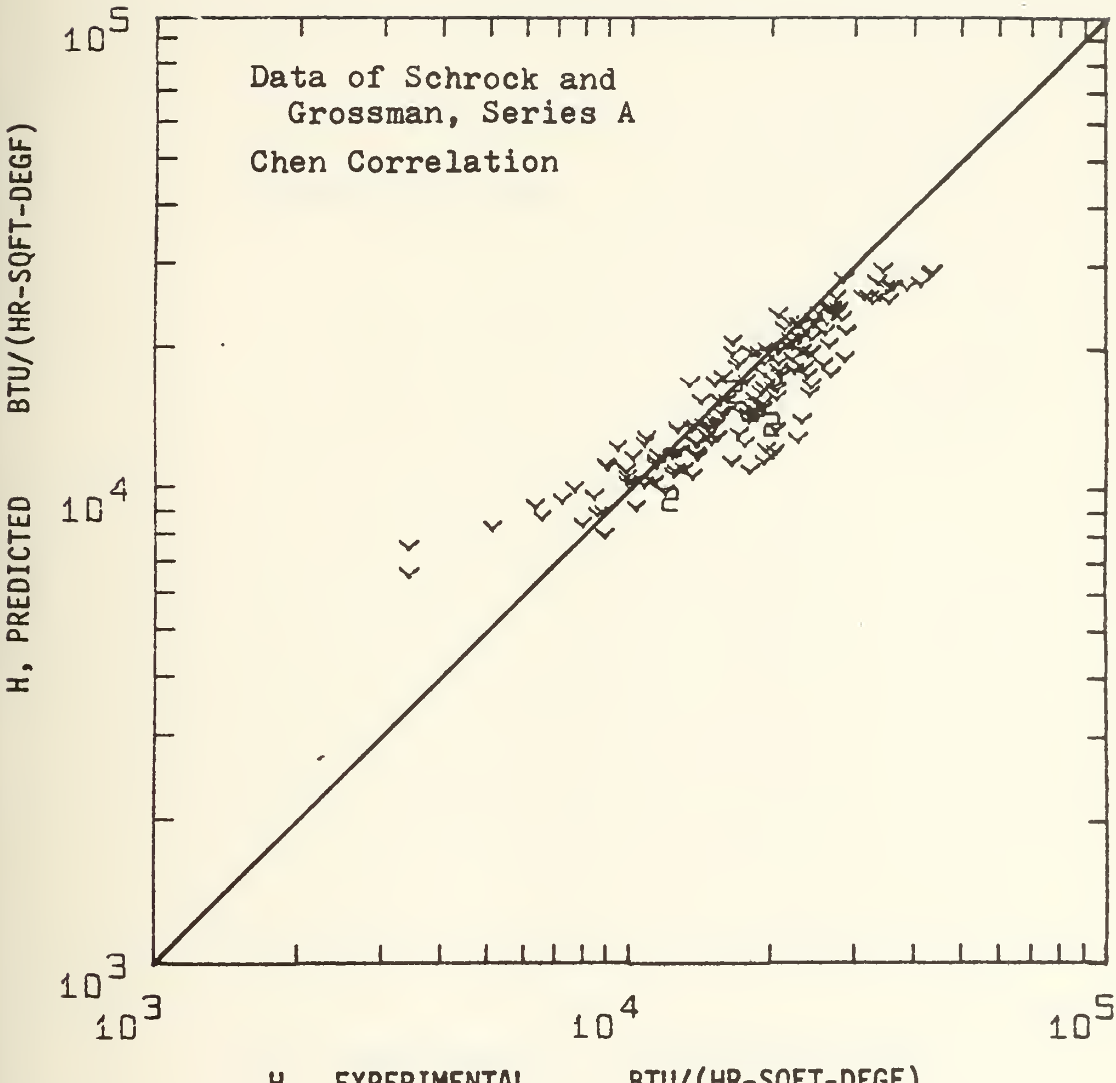

Data of Dengler
Chen Correlation
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5

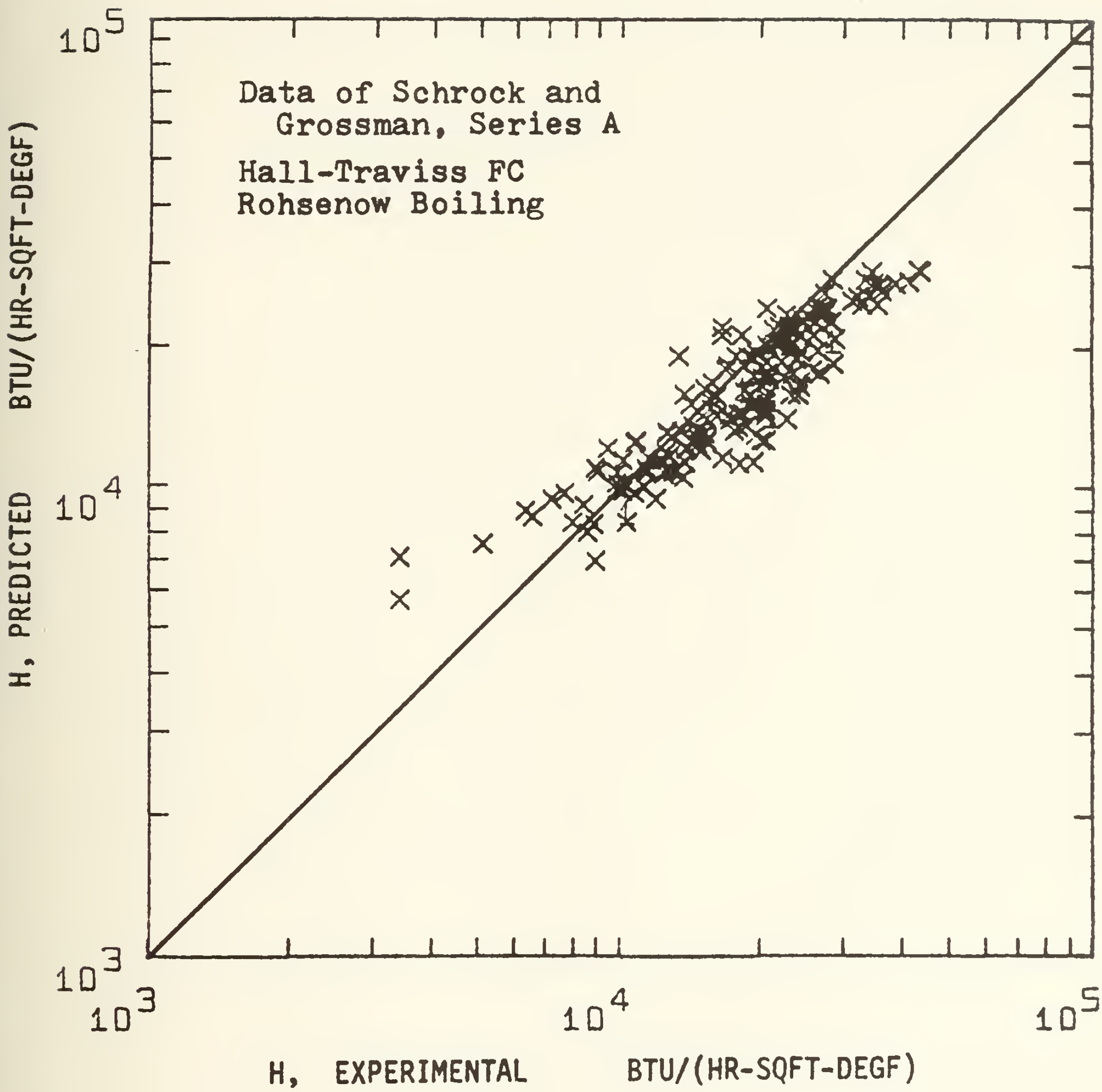


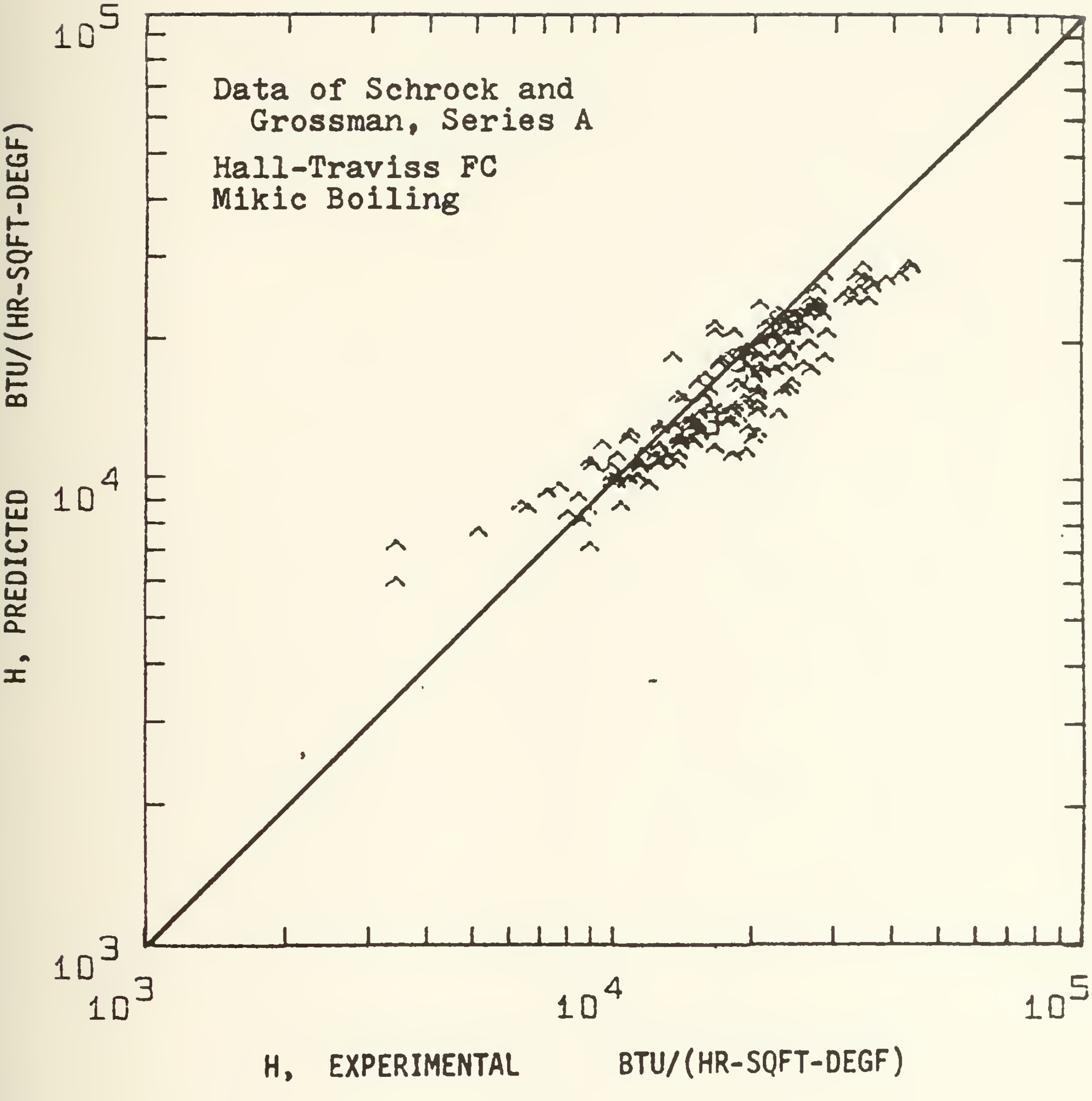
Data of Dengler
Hall-Traviss FC
Rohsenow Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5


Data of Dengler
Hall-Traviss FC
Mikic Boiling
10^5
10^4
10^3
10^3
10^4
10^5
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)

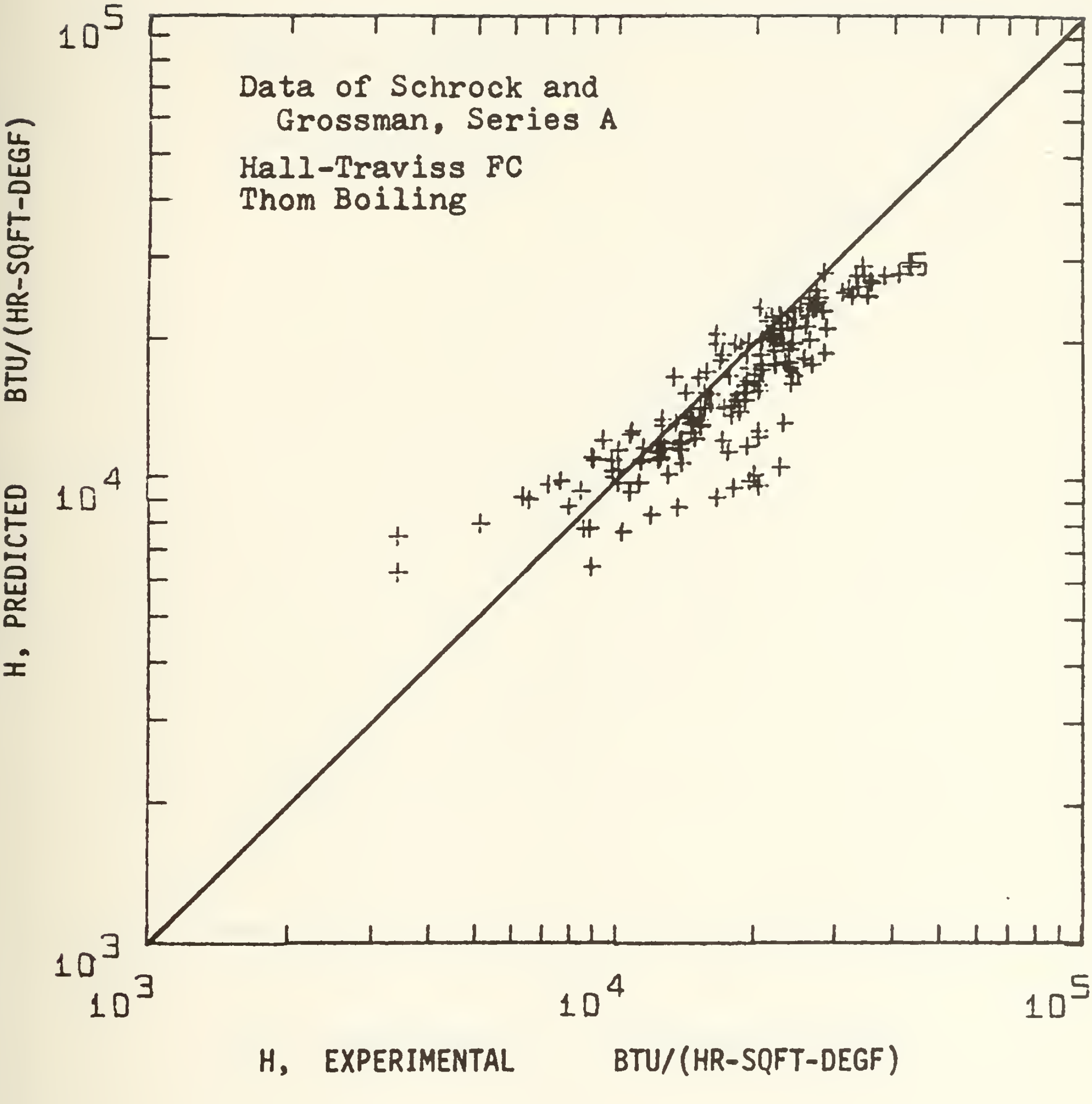

Data of Dengler
Hall-Traviss FC
Thom Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^5
10^4
10^3

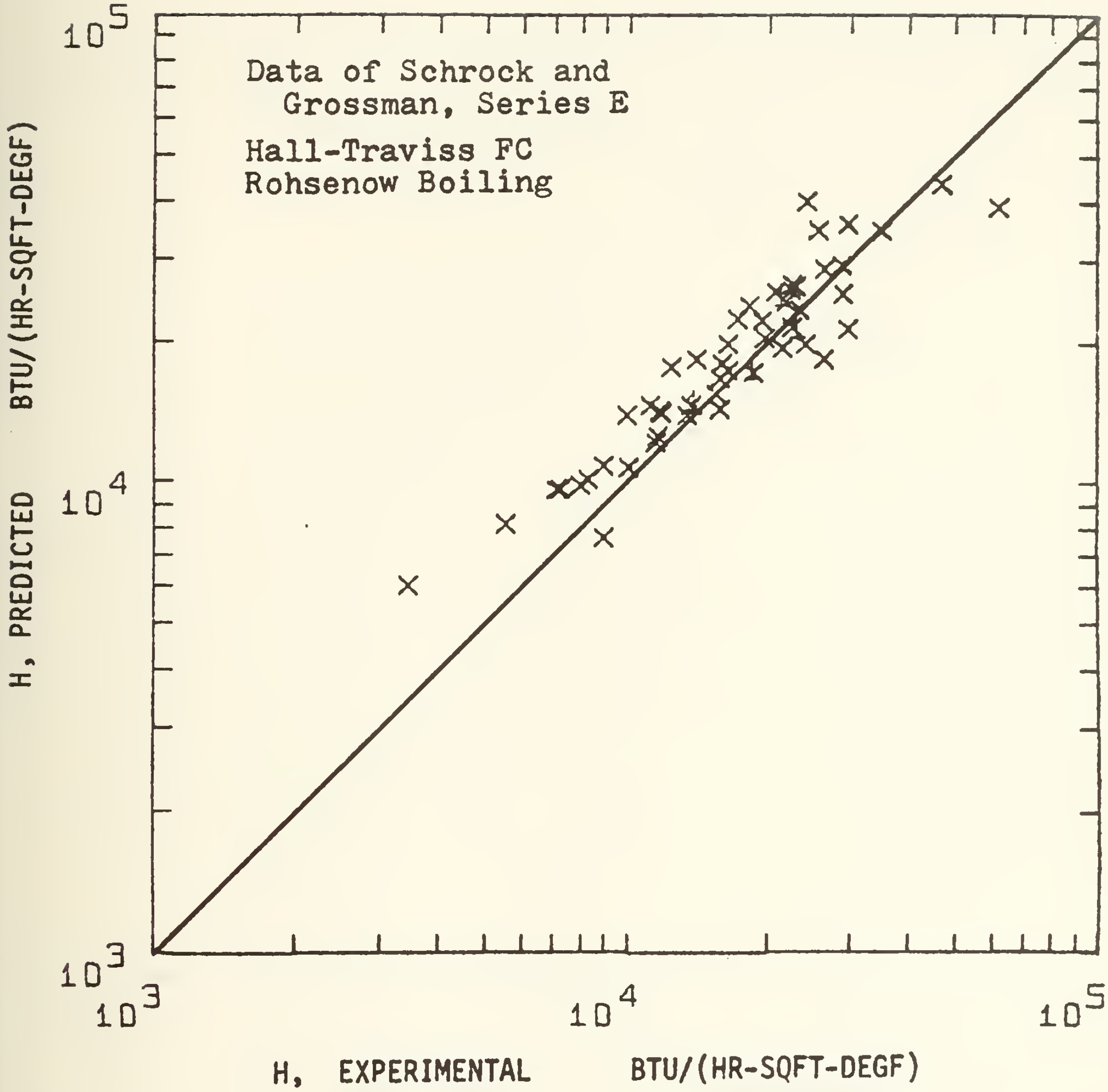

Data of Schrock and
Grossman, Series A
Chen Correlation
10^5
10^4
10^3
10^3
10^4
10^5
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)

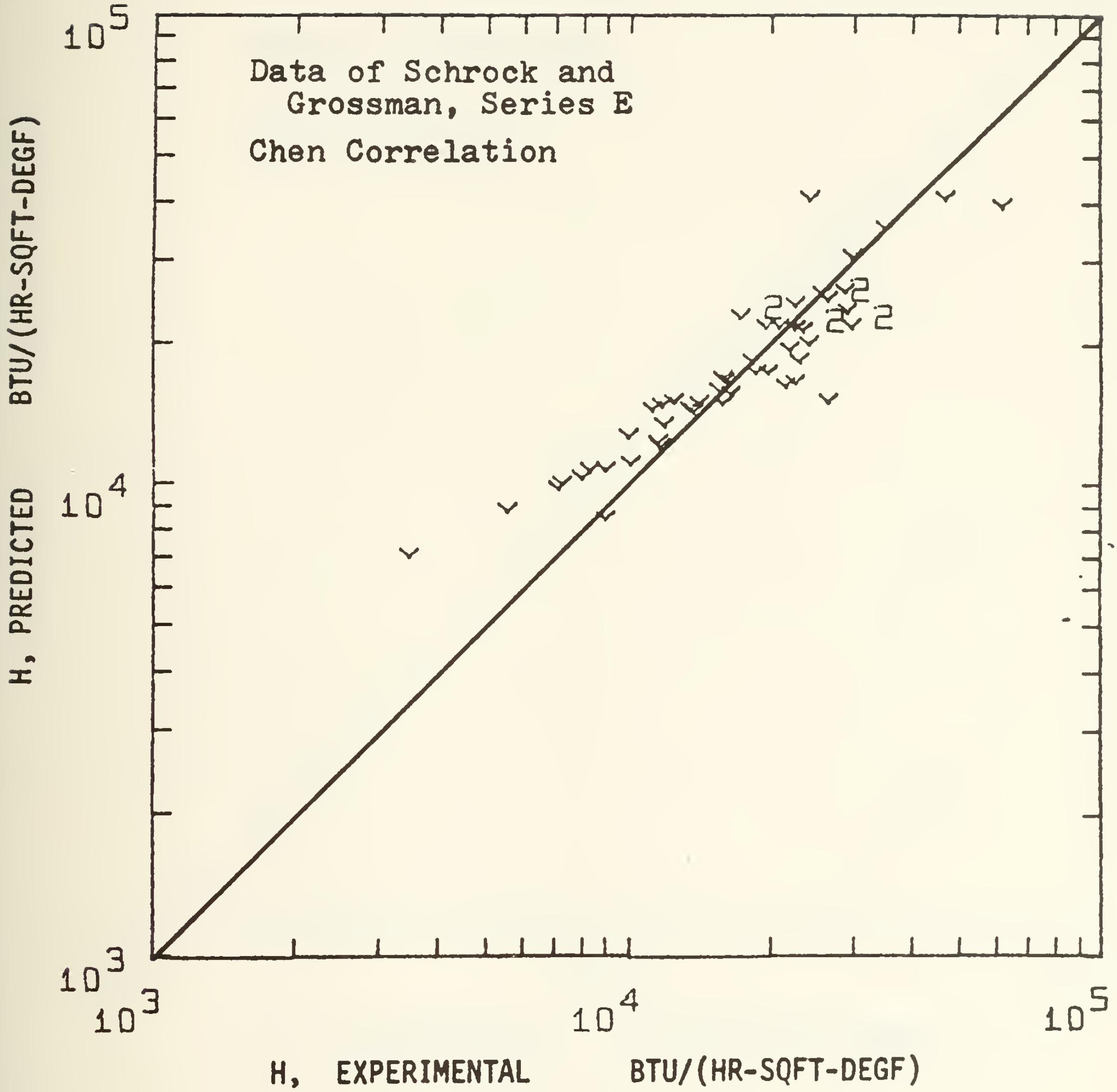

Data of Schrock and Grossman, Series A
Hall-Traviss FC
Rohsenow Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5

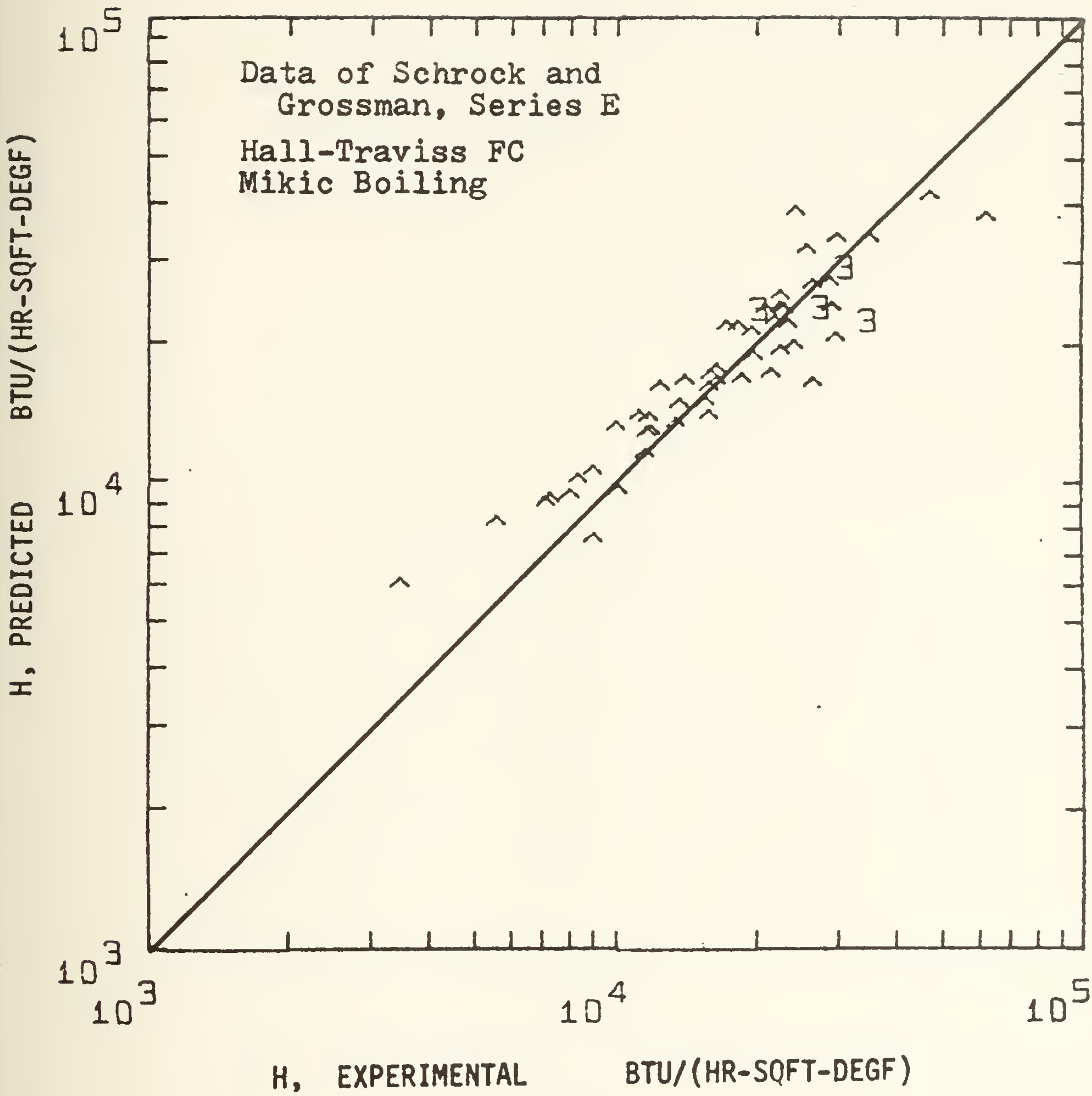


Data of Schrock and Grossman, Series A
Hall-Traviss FC
Mikic Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^5
10^4
10^3

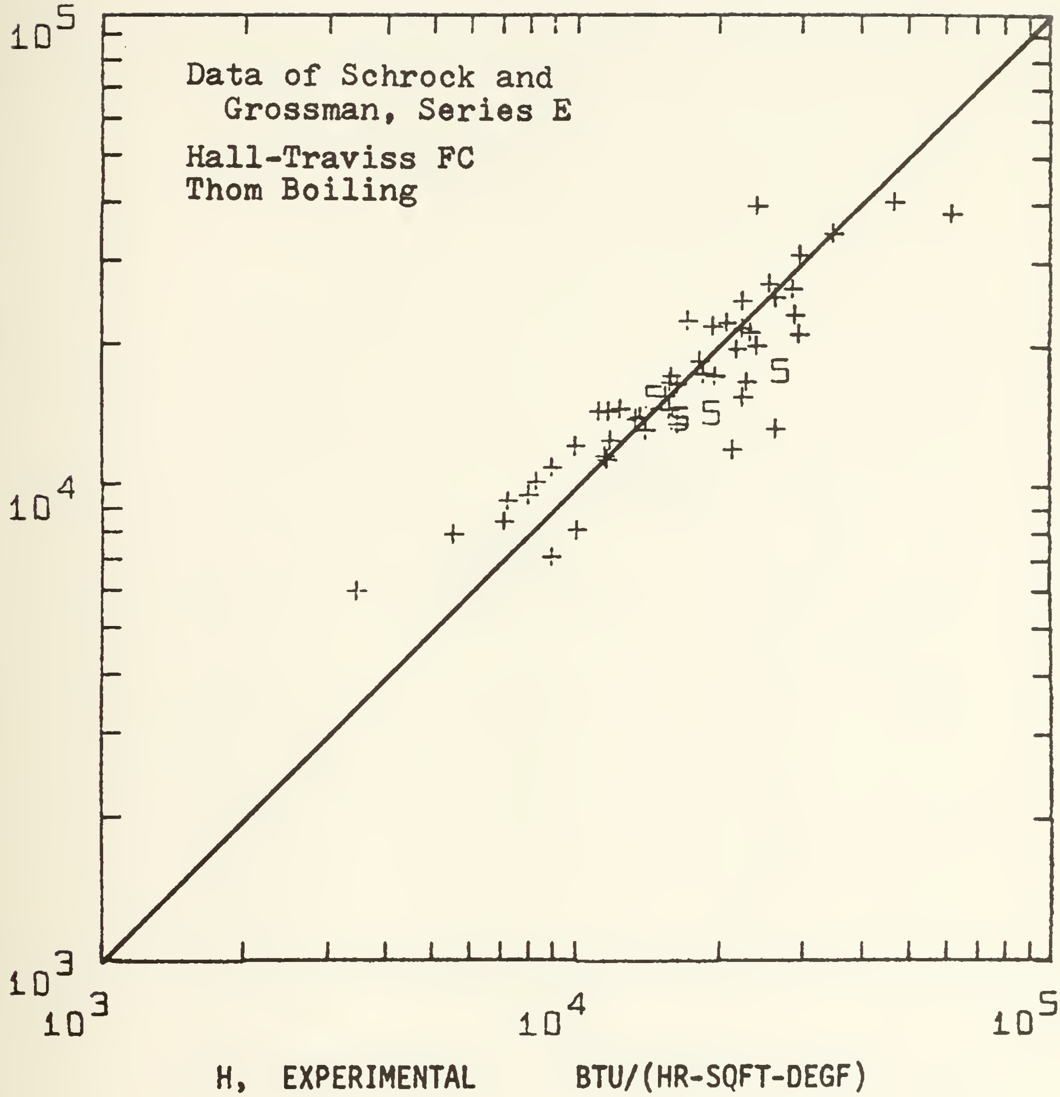

Data of Schrock and
Grossman, Series A
Hall-Traviss FC
Thom Boiling
10^5
10^4
10^3
10^3
10^4
10^5
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)

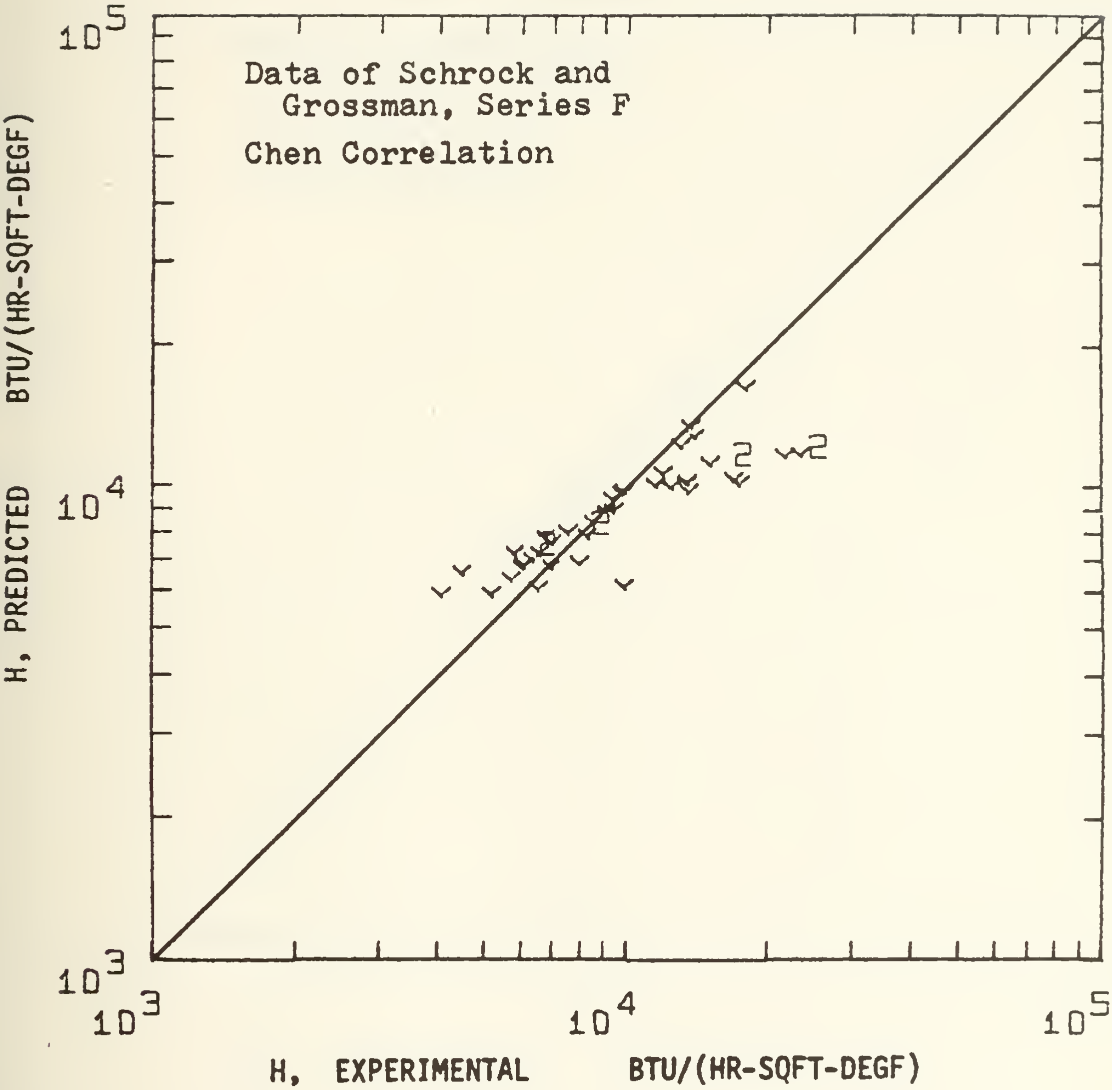

Data of Schrock and
Grossman, Series E
Hall-Traviss FC
Rohsenow Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5
10^3
10^4
10^5


Data of Schrock and
Grossman, Series E
Chen Correlation
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5
10^3
10^4
10^5
2

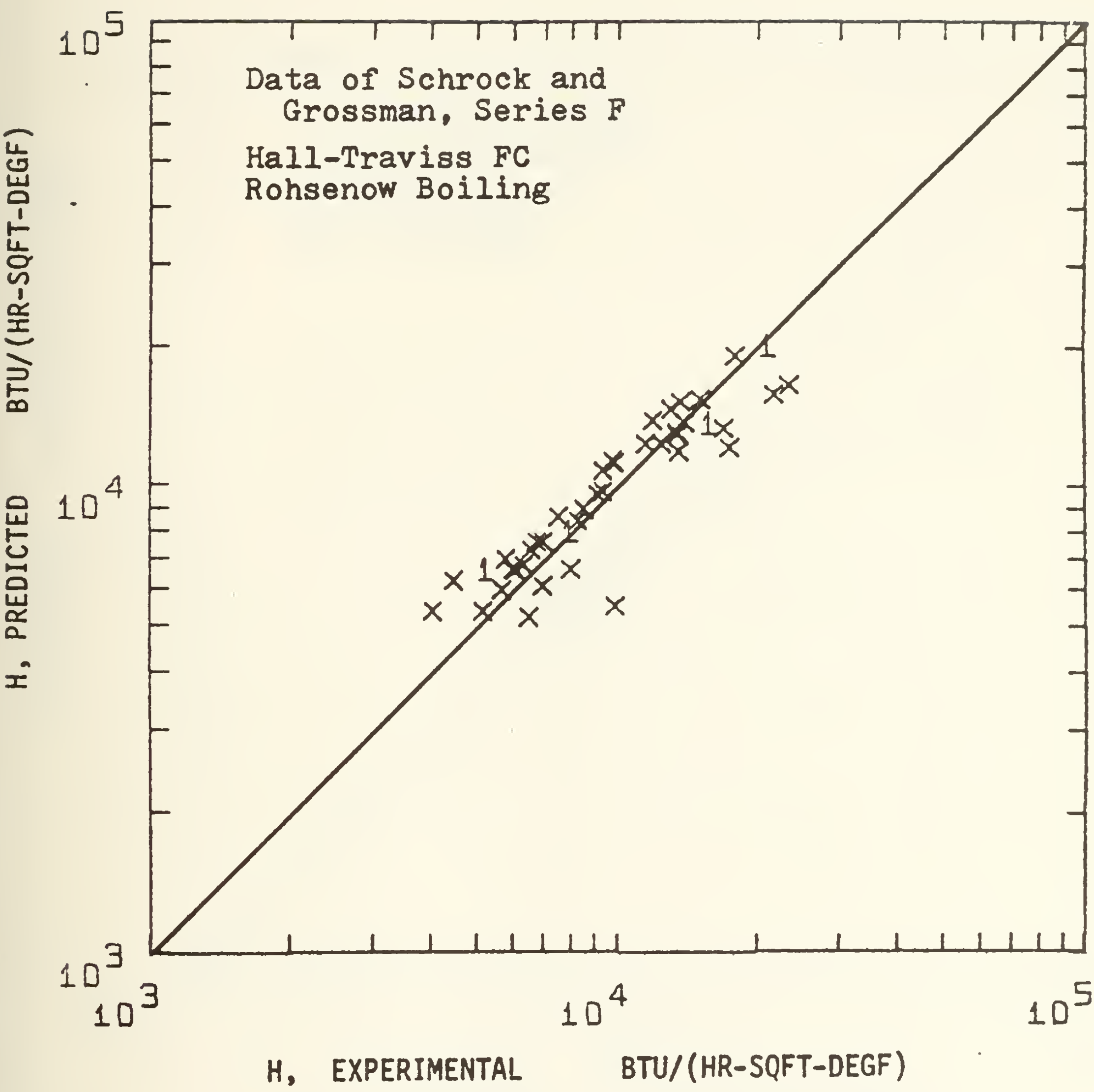


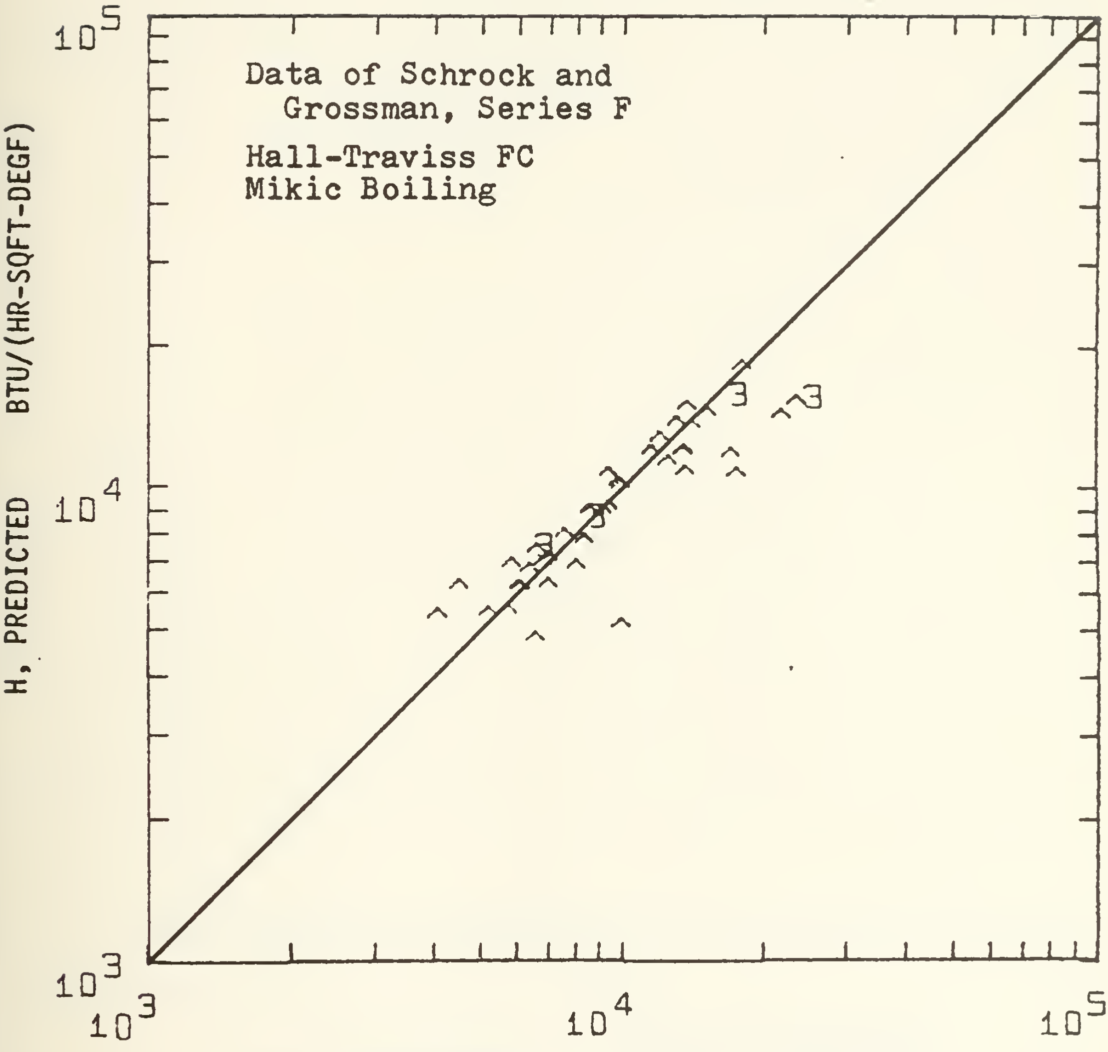
Data of Schrock and Grossman, Series E
Hall-Traviss FC
Mikic Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5

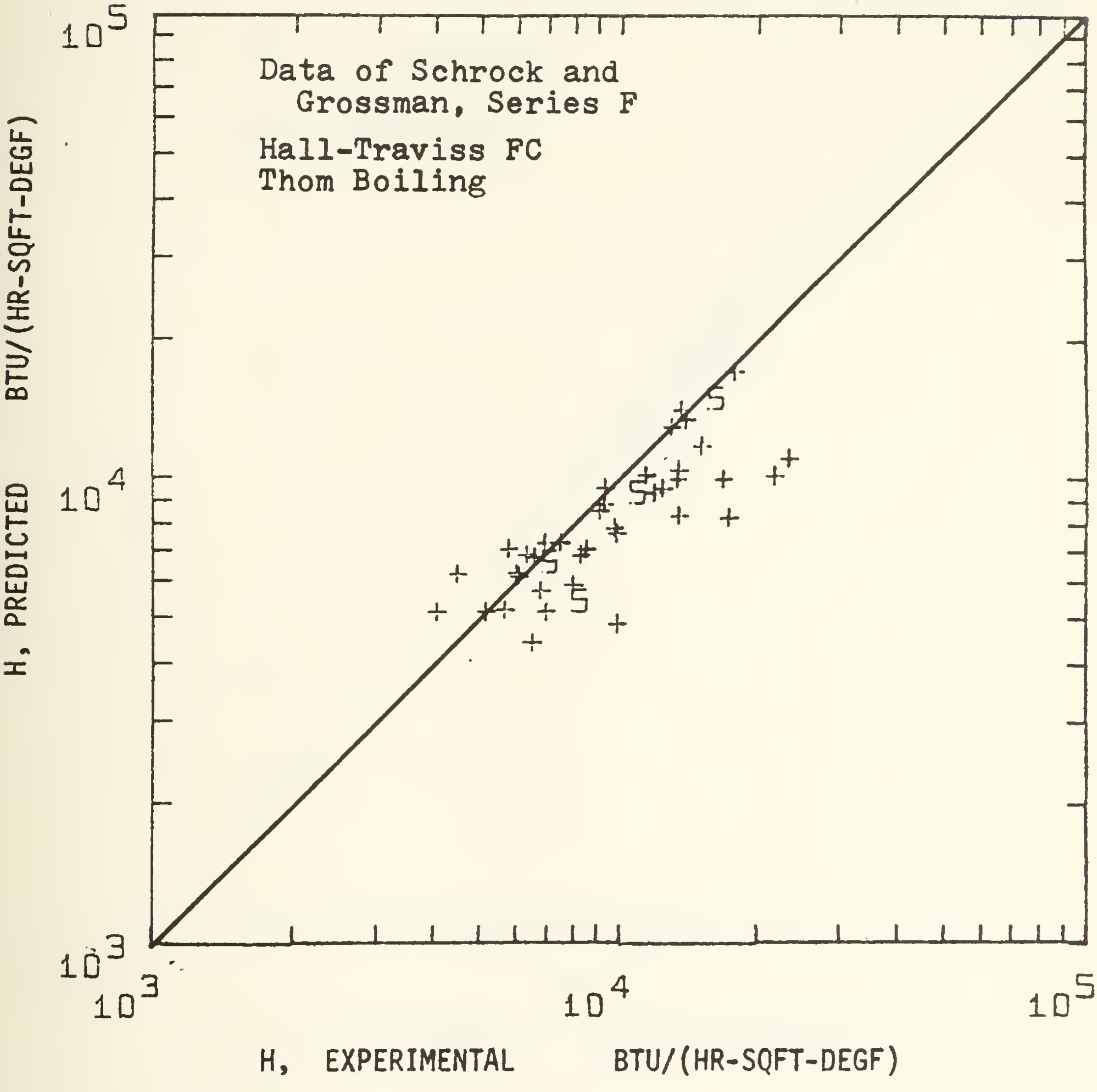

Data of Schrock and Grossman, Series E
Hall-Traviss FC
Thom Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5
S



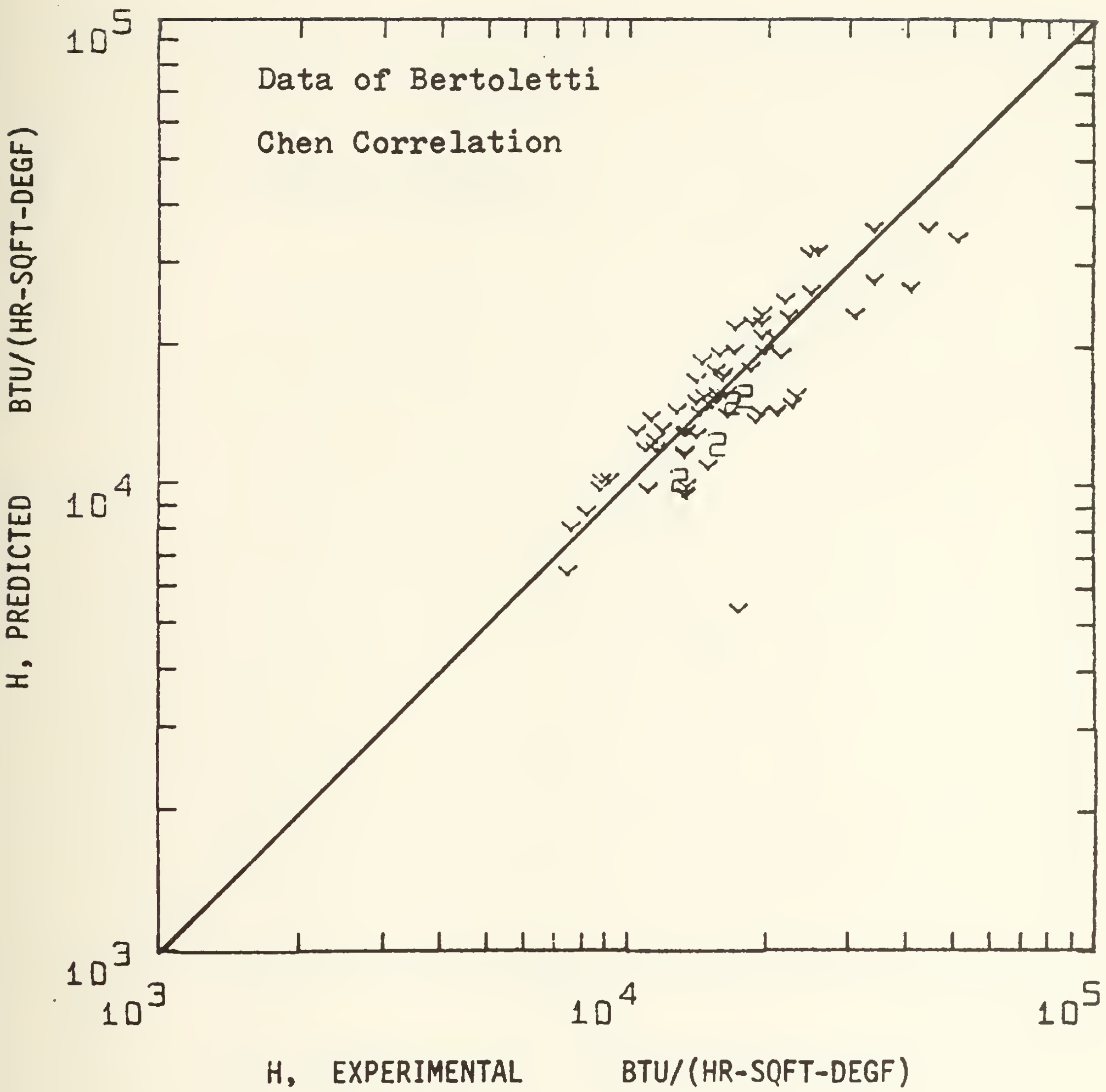
Data of Schrock and Grossman, Series F
Chen Correlation
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5


Data of Schrock and Grossman, Series F
Hall-Traviss FC
Rohsenow Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5

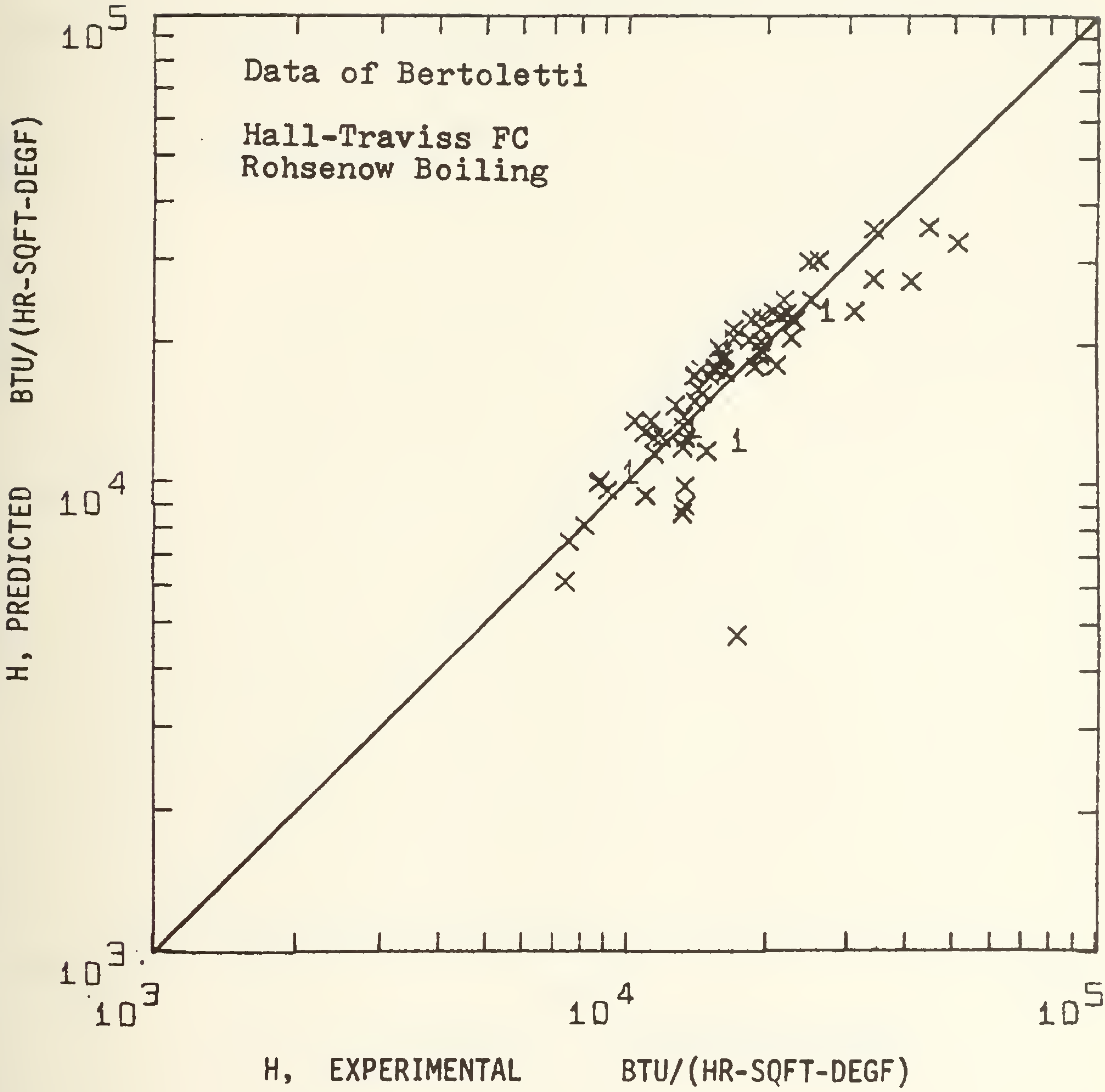

Data of Schrock and
Grossman, Series F
Hall-Traviss FC
Mikic Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5

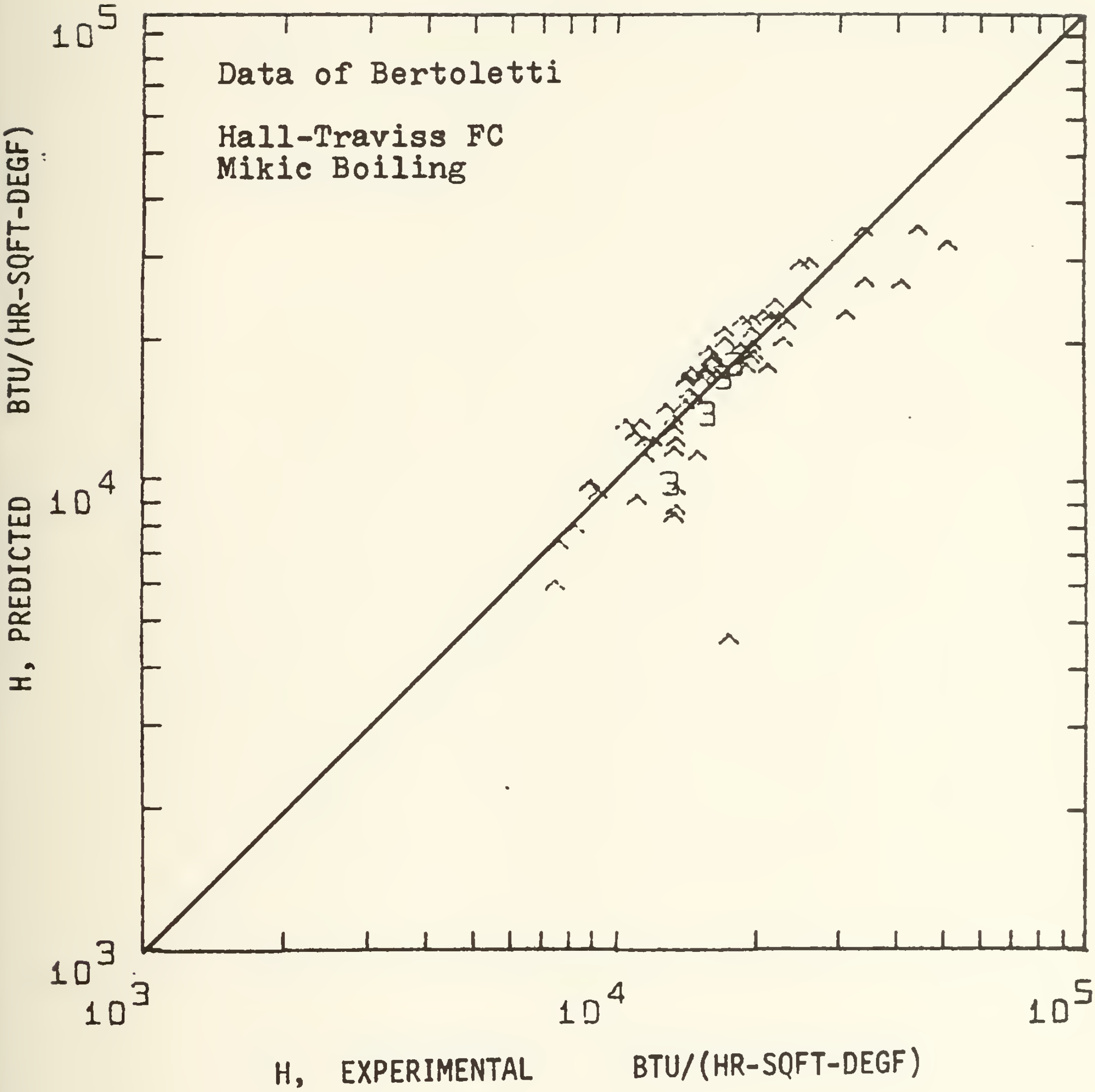


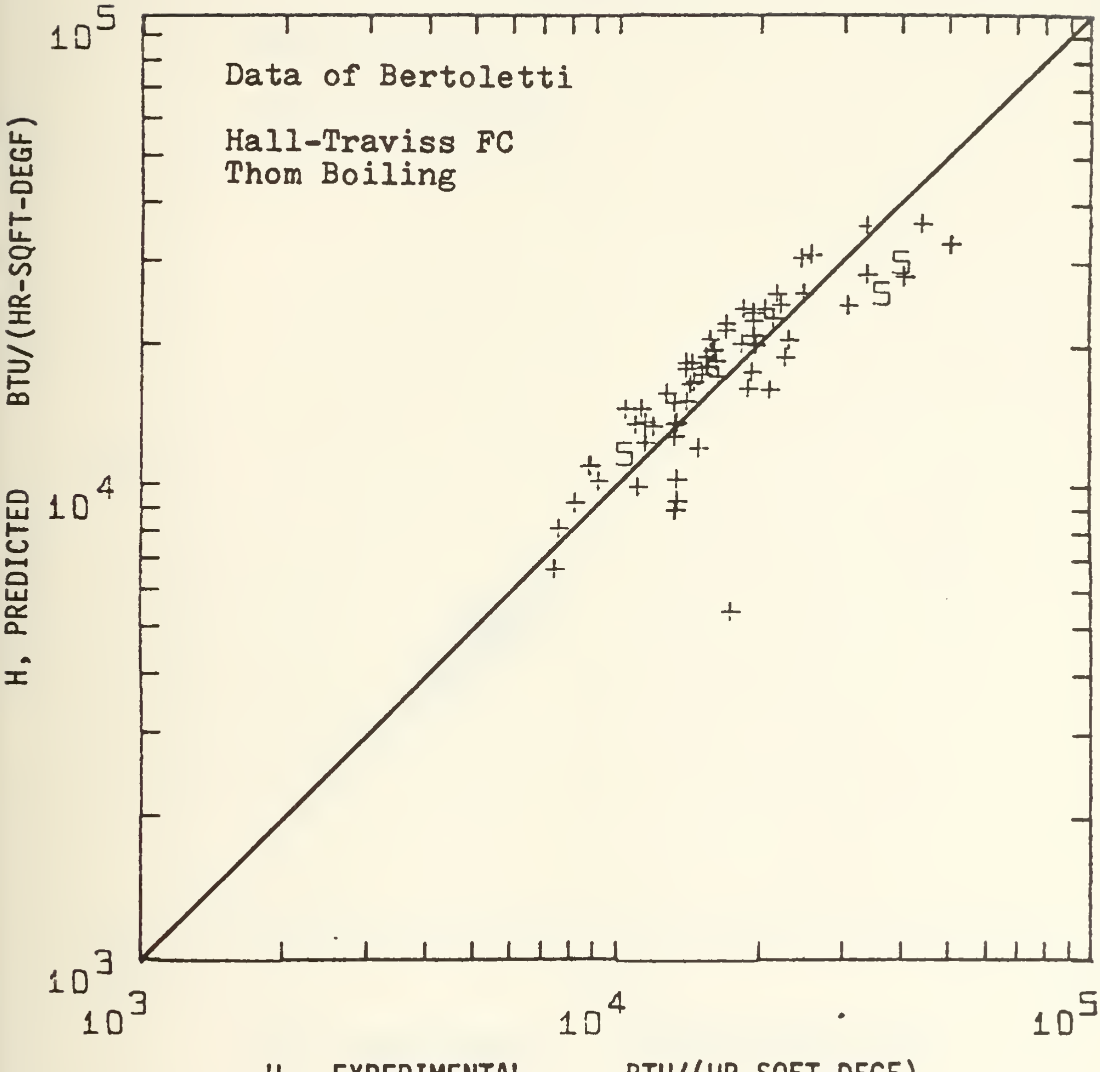
Data of Schrock and
Grossman, Series F
Hall-Traviss FC
Thom Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5



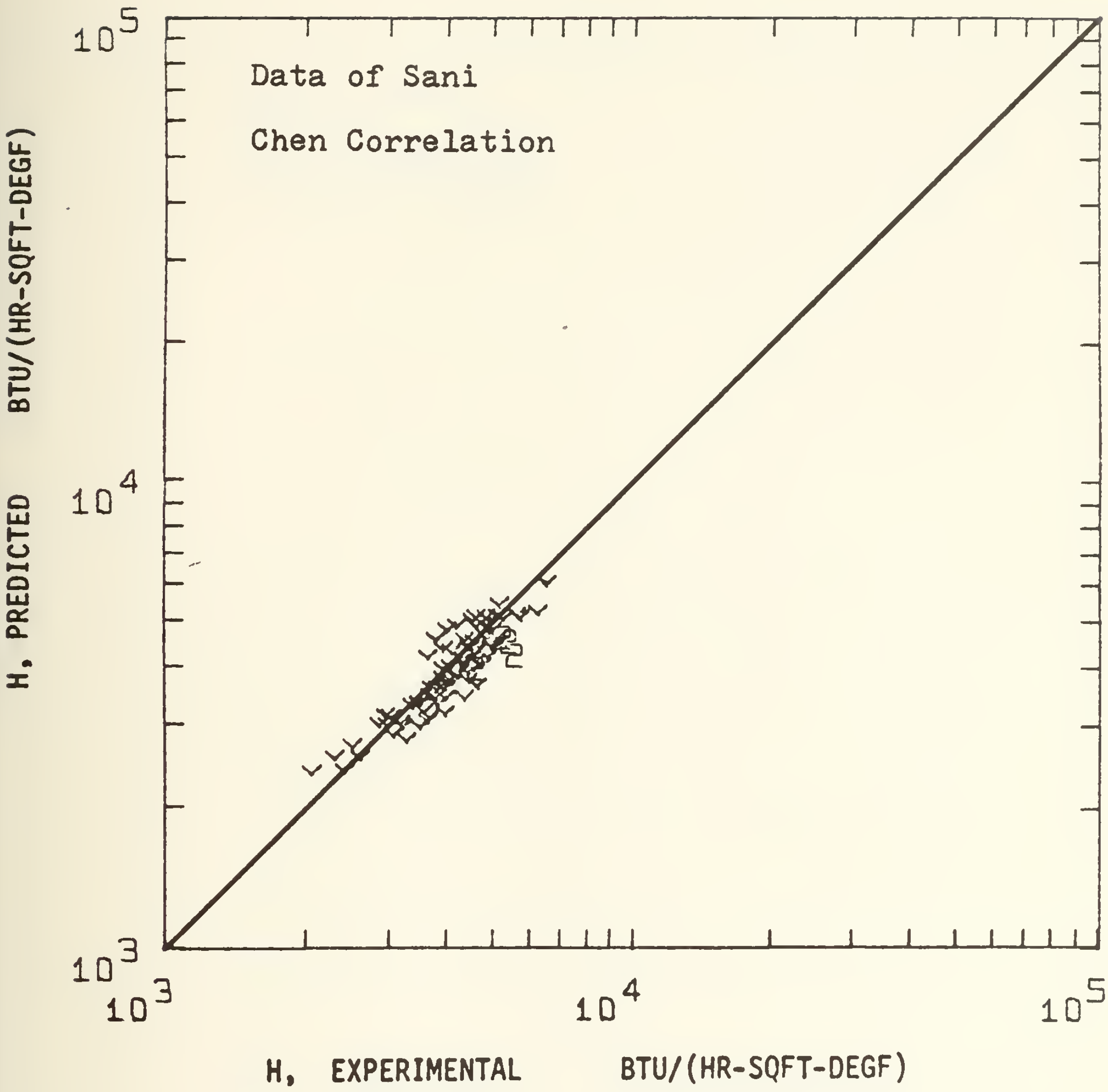
Data of Bertoletti
Chen Correlation
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5


Data of Bertoletti
Hall-Traviss FC
Rohsenow Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^5
10^4
10^3
10^3
10^4
10^5


Data of Bertoletti
Hall-Traviss FC
Mikic Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5



Data of Bertoletti
Hall-Traviss FC
Thom Boiling
10^5
10^4
10^3
10^3
10^4
10^5
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)


Data of Sani
Chen Correlation
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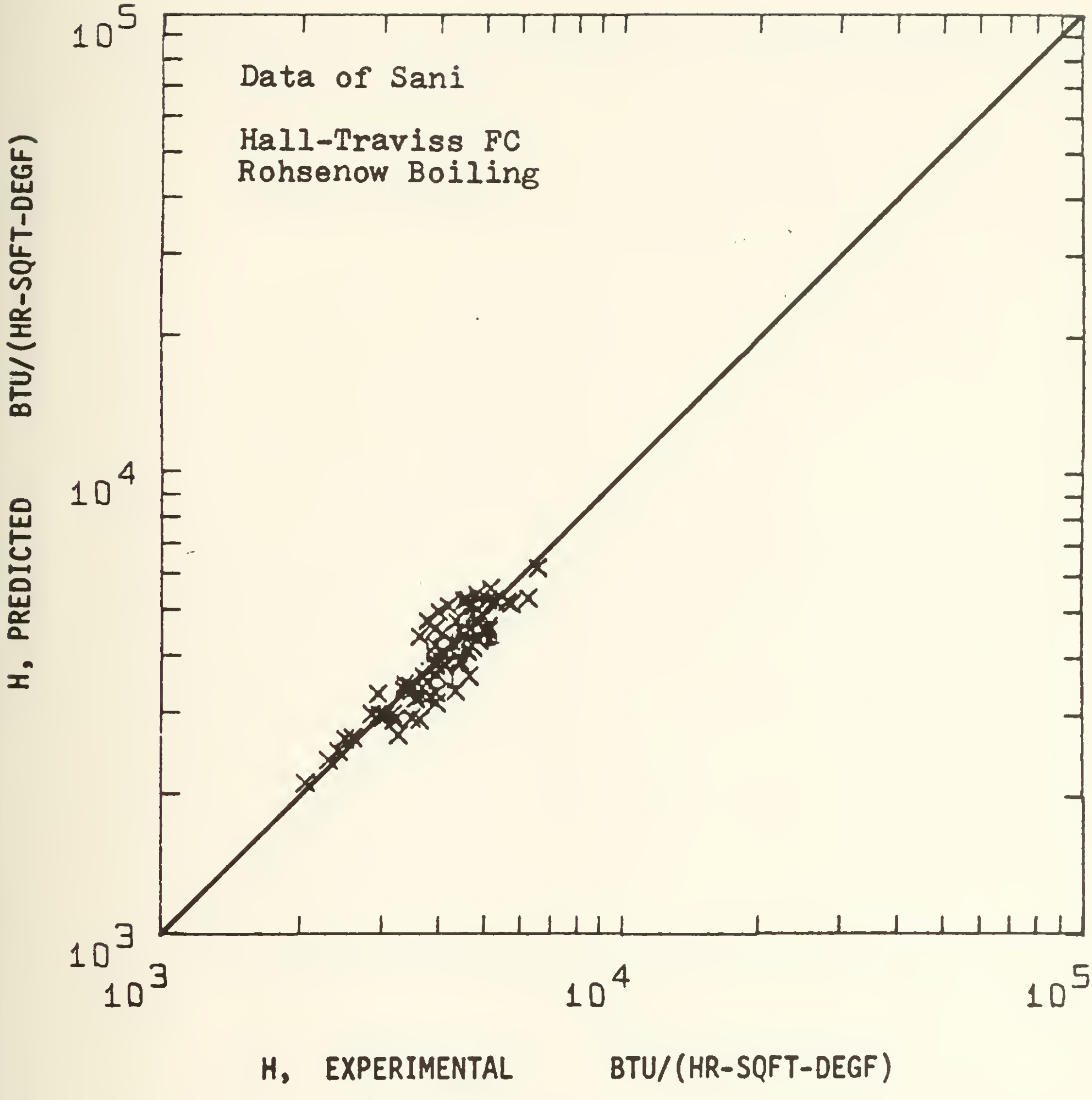
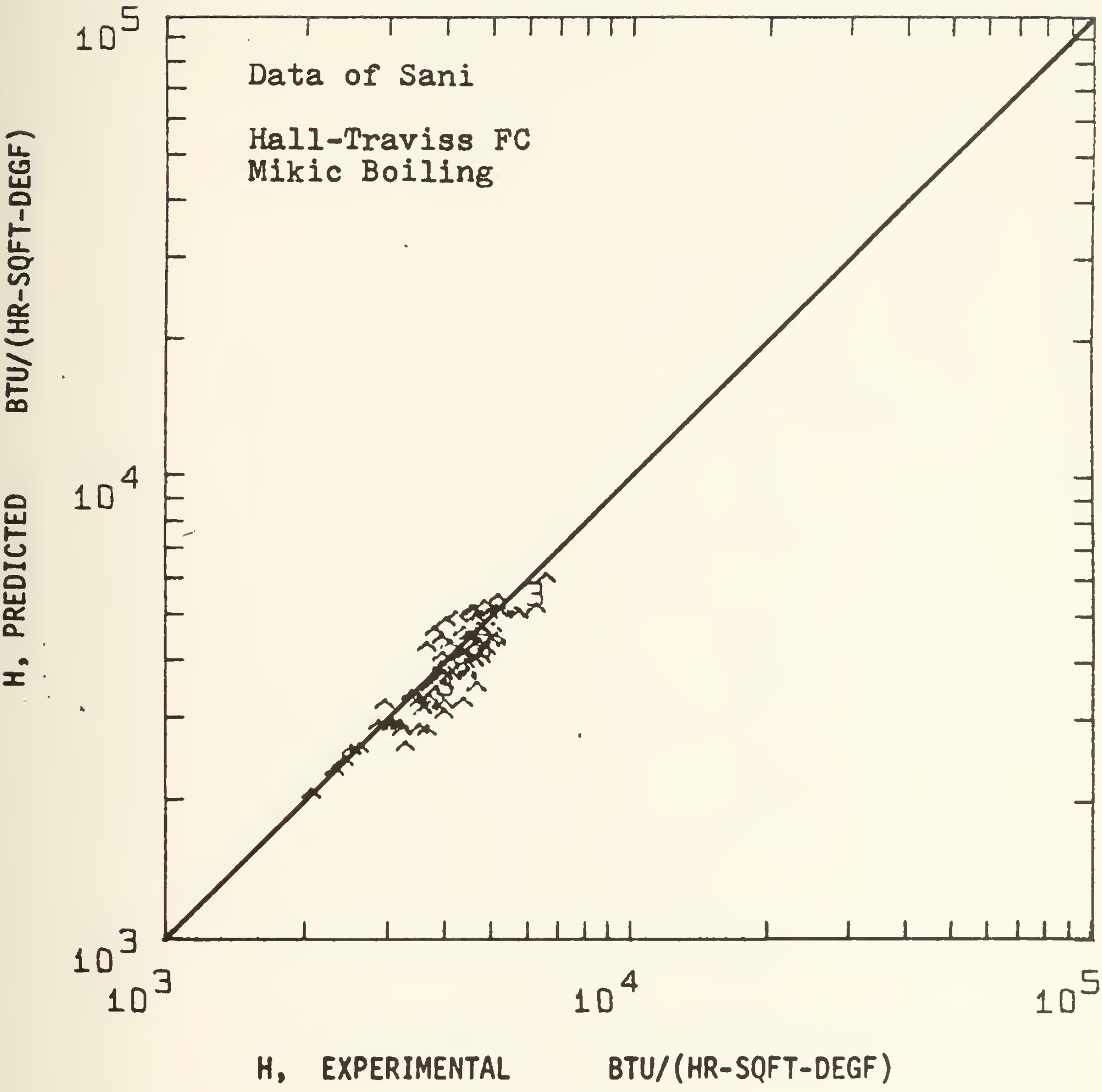
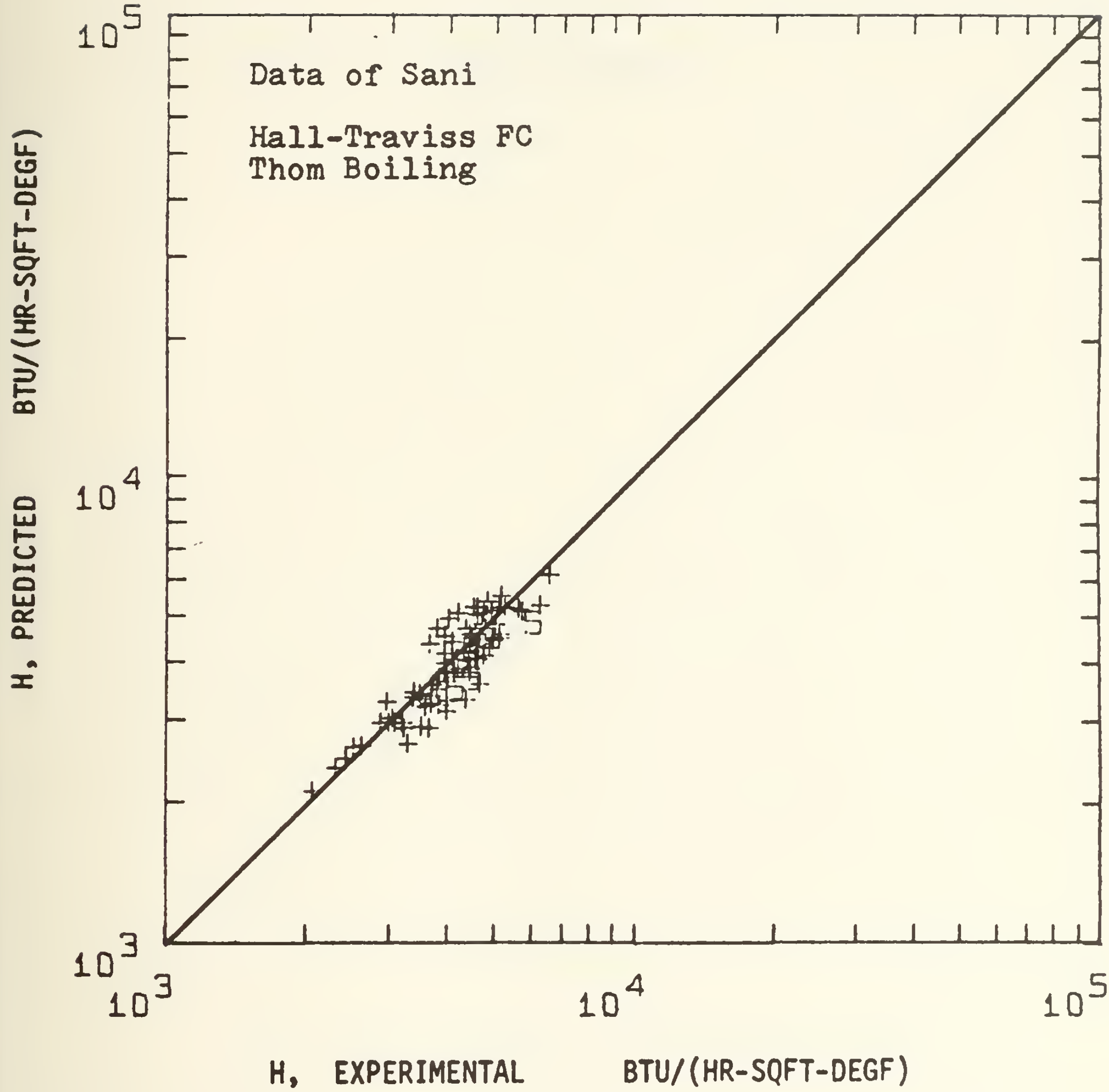
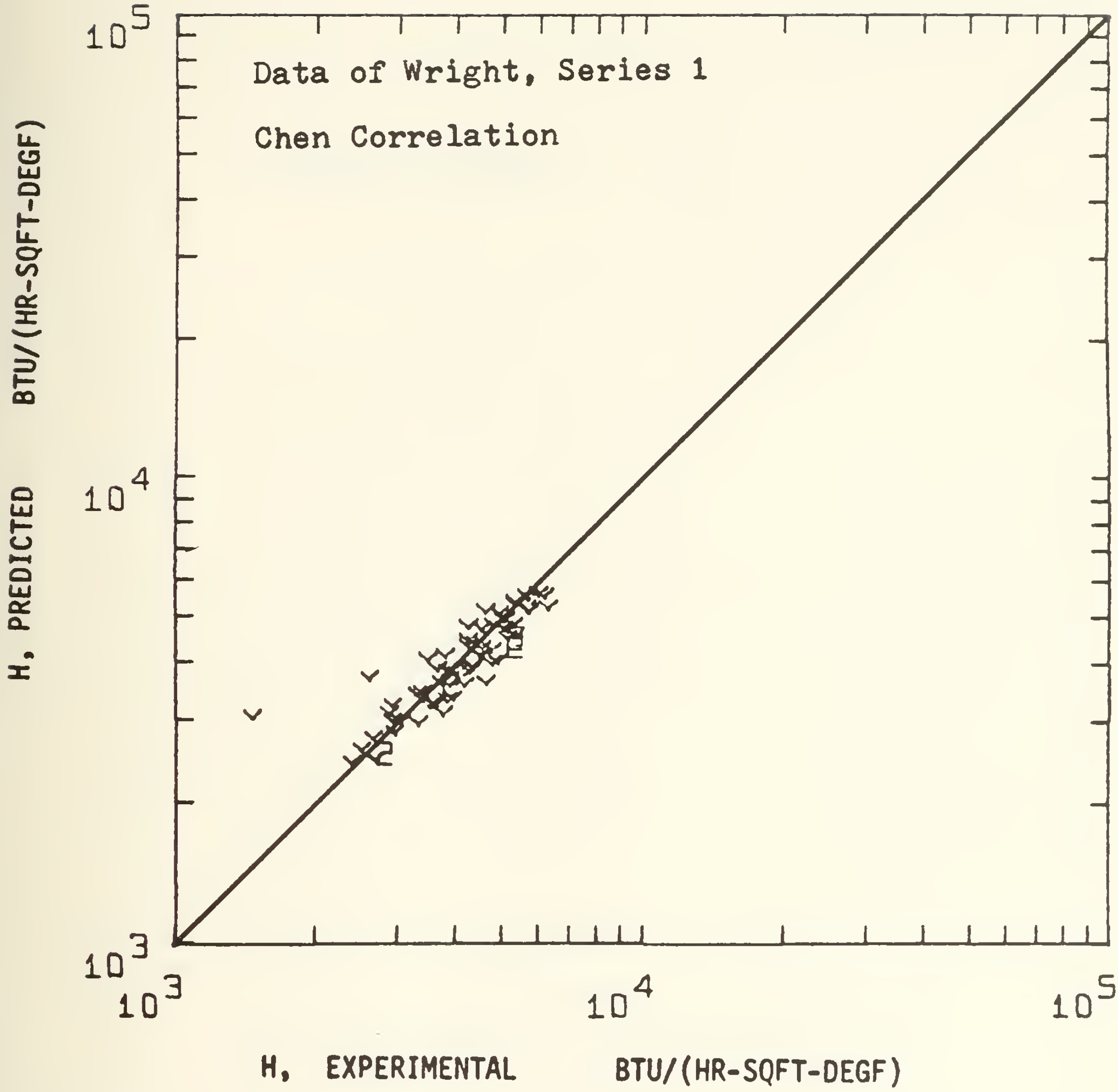
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5



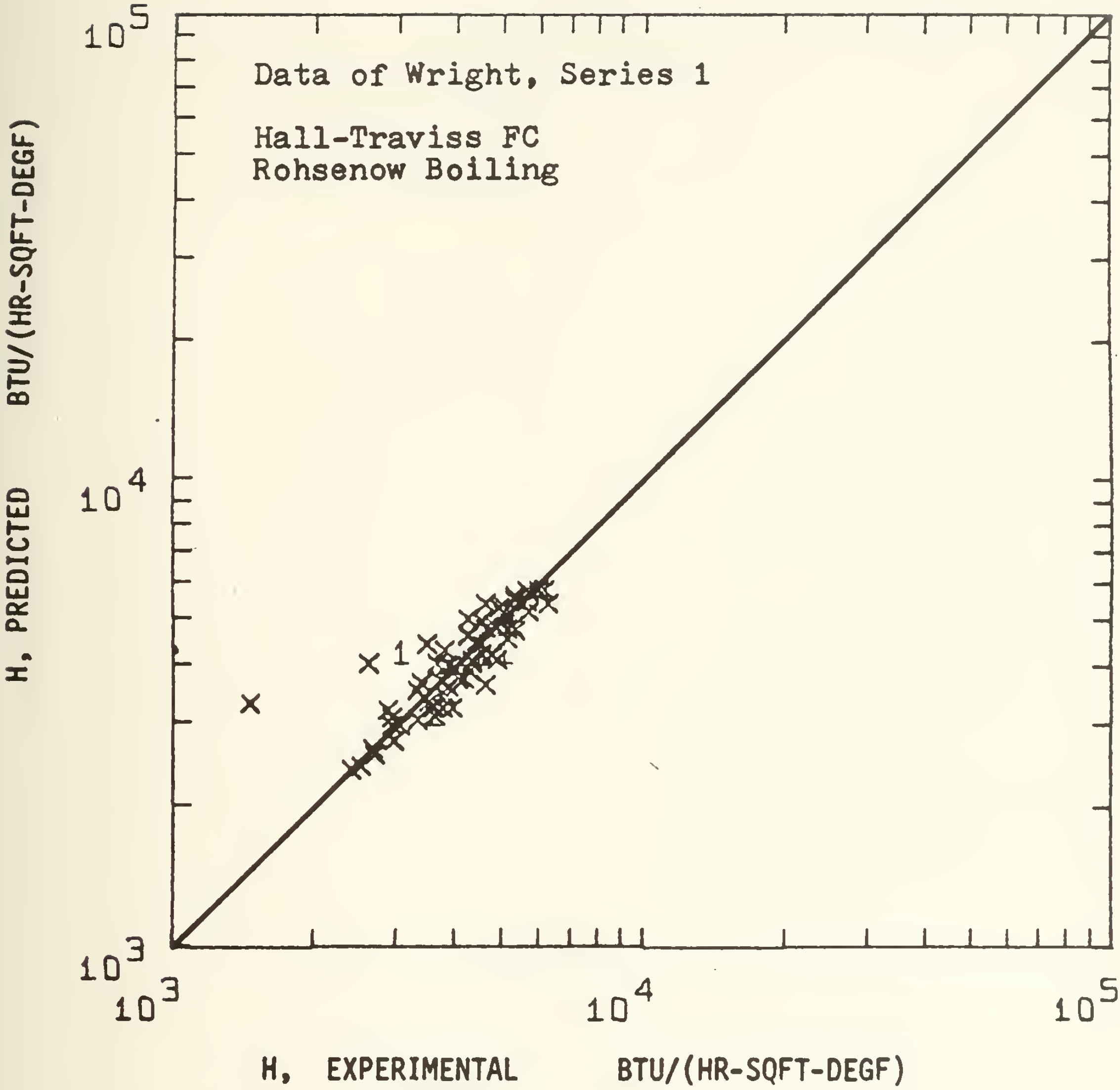
Data of Sani
Hall-Traviss FC
Rohsenow Boiling
10^5
10^4
10^3
H, PREDICTED BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)


Data of Sani
Hall-Traviss FC
Mikic Boiling
10^5
10^4
10^3
H, PREDICTED BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)

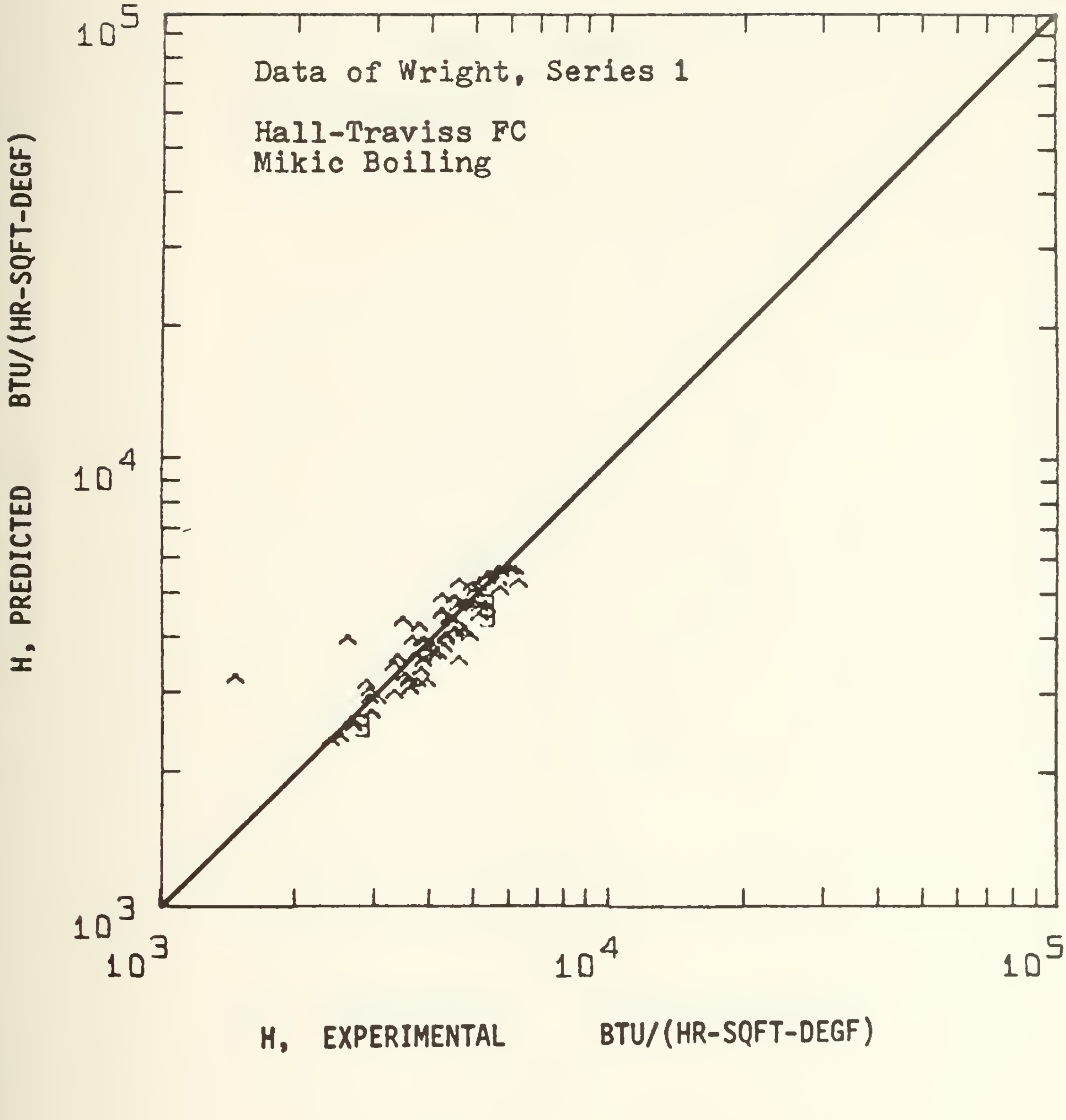

Data of Sani
Hall-Traviss FC
Thom Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5

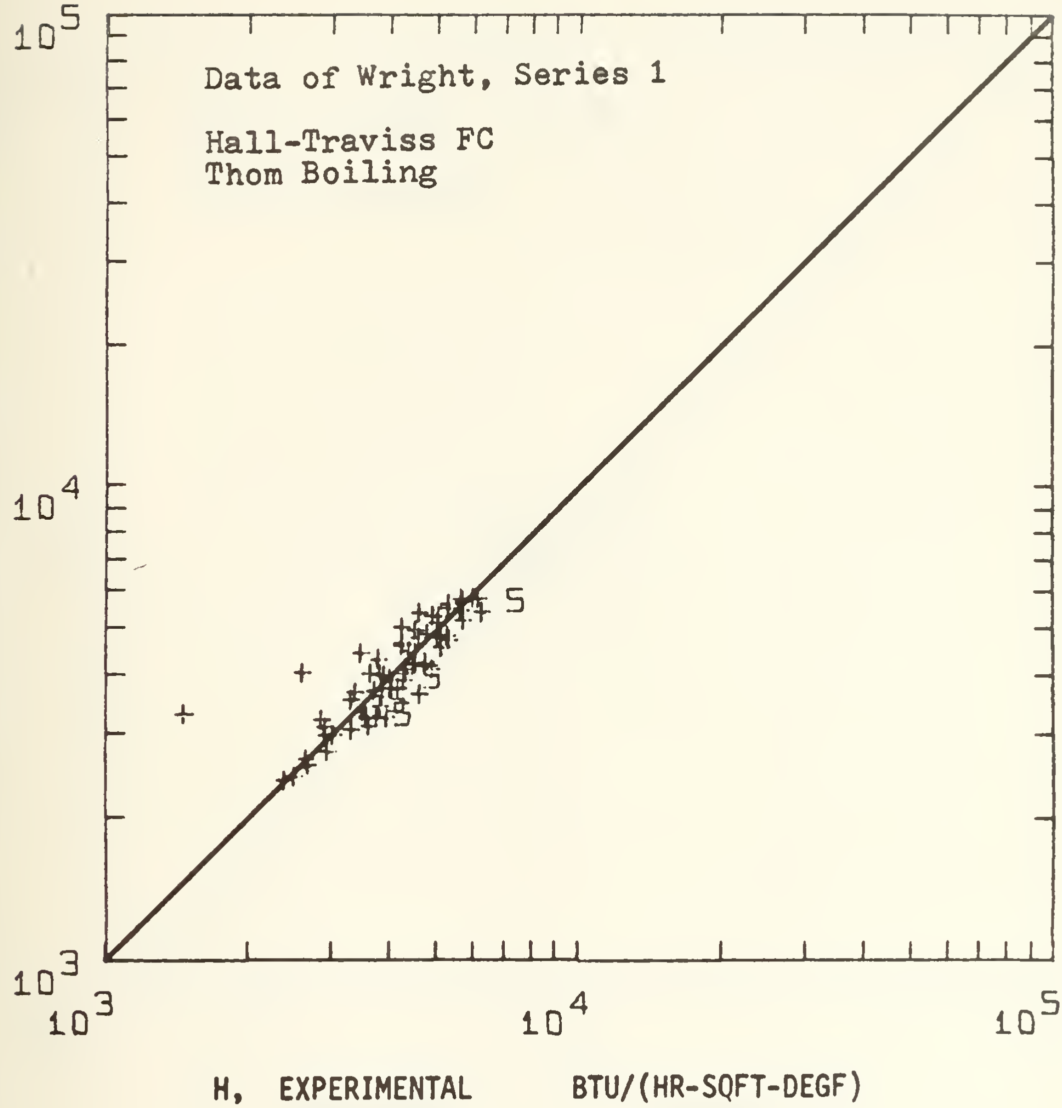


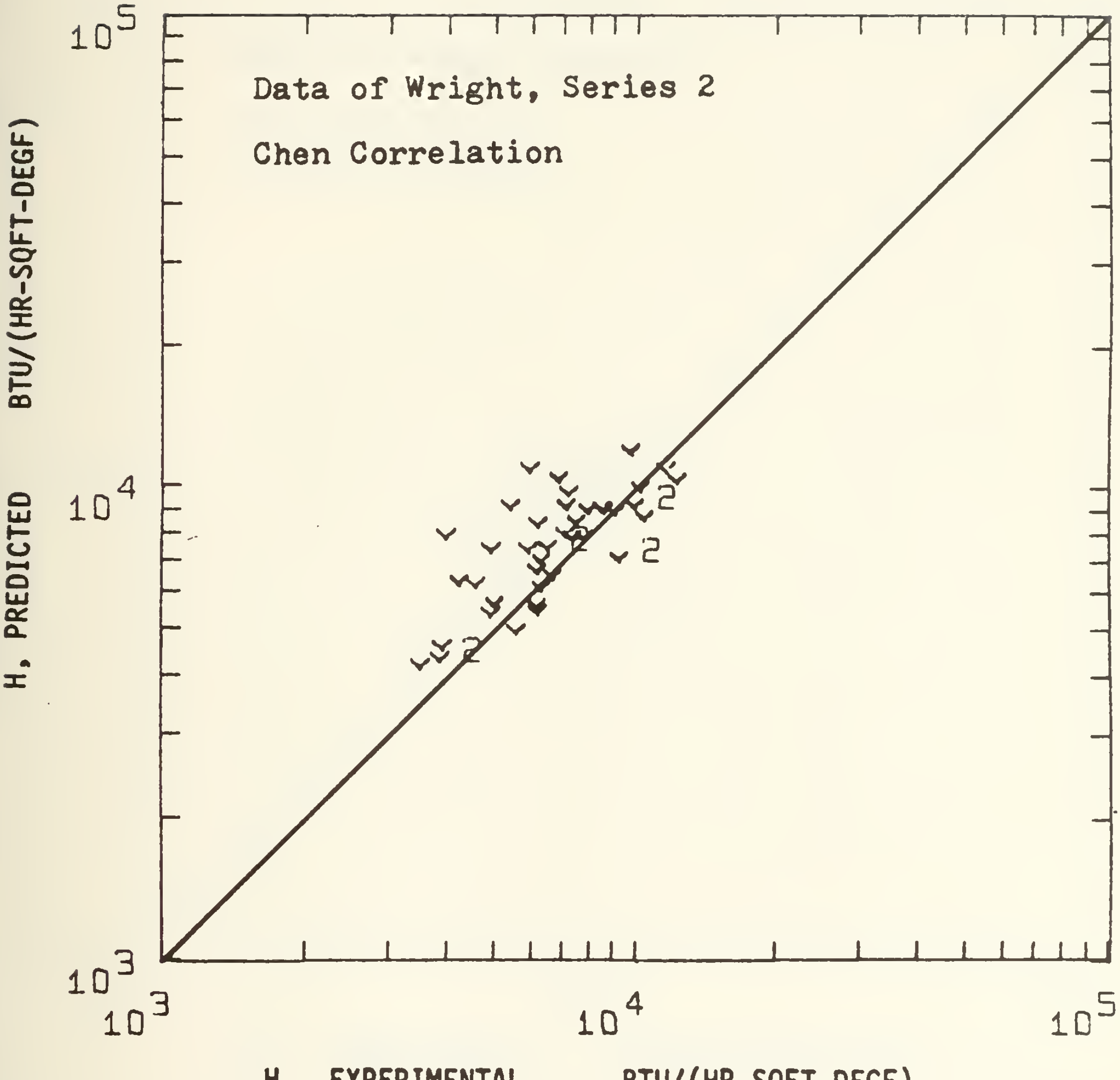
Data of Wright, Series 1
Chen Correlation
10^5
10^4
10^3
10^3
10^4
10^5
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)



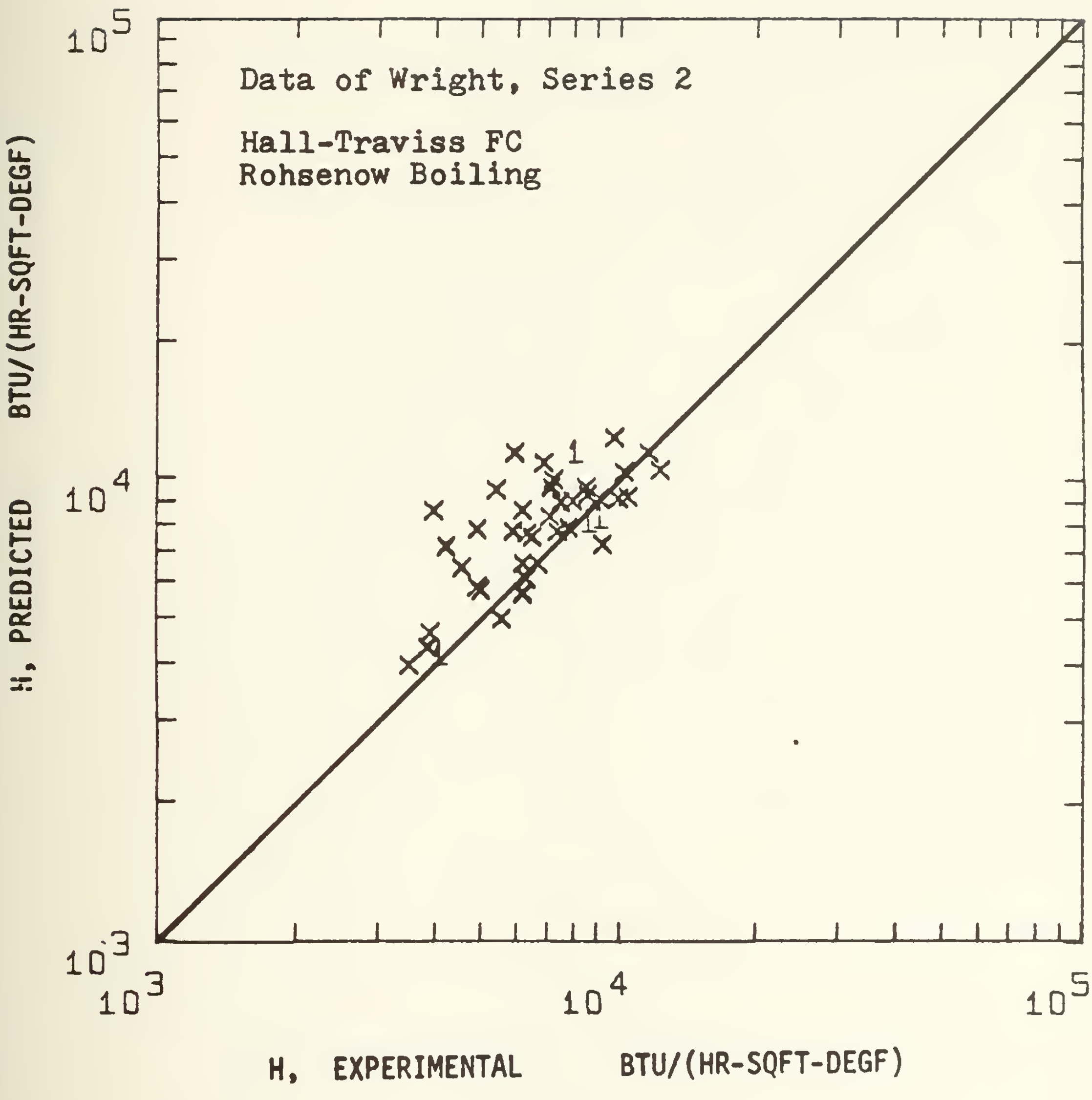
Data of Wright, Series 1
Hall-Traviss FC
Rohsenow Boiling
1
10^5
10^4
10^3
10^3
10^4
10^5
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)

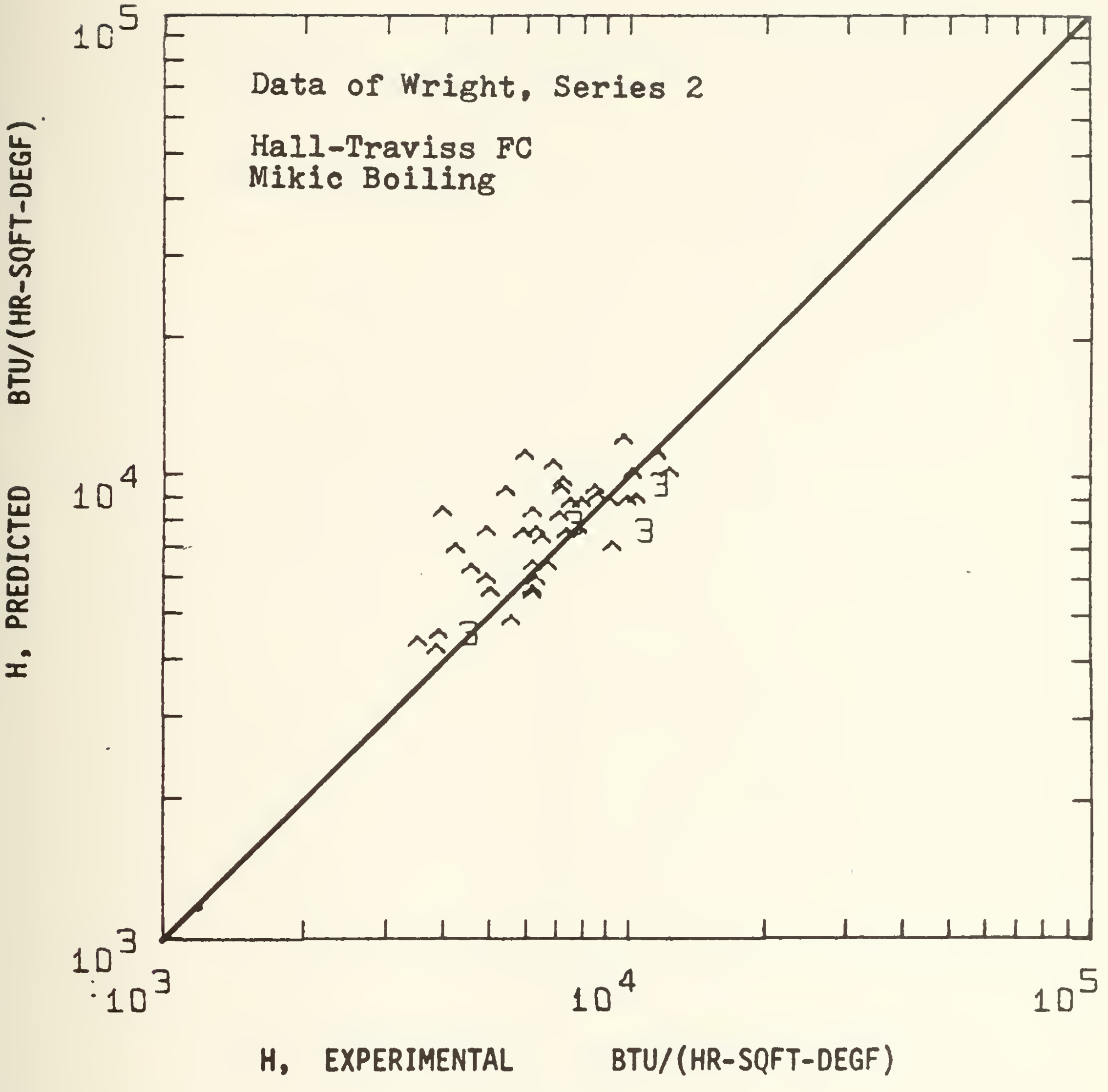

Data of Wright, Series 1
Hall-Traviss FC
Mikic Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5

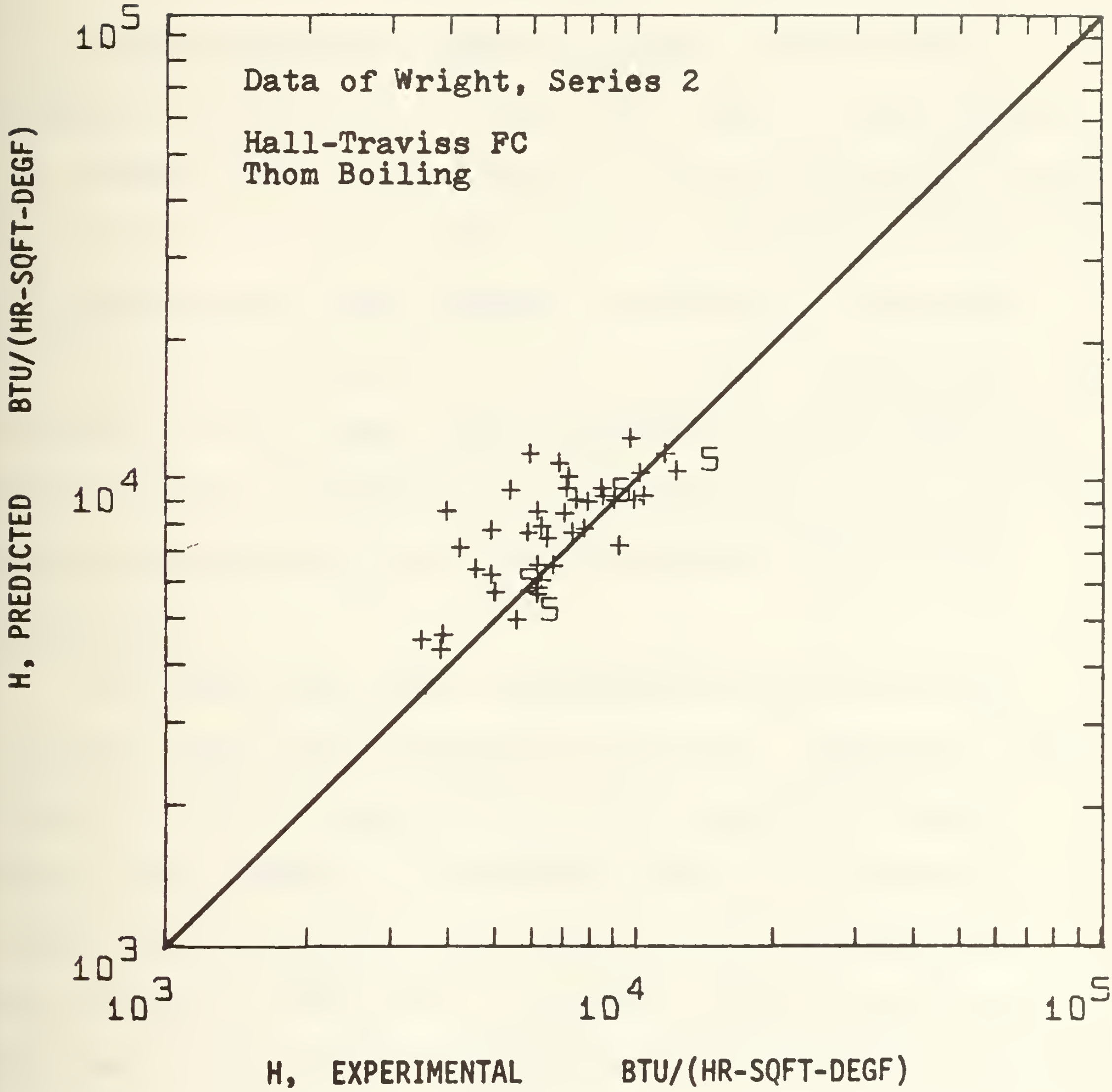

Data of Wright, Series 1
Hall-Traviss FC
Thom Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5
5



Data of Wright, Series 2
Chen Correlation
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^5
10^4
10^3
10^3
10^4
10^5


Data of Wright, Series 2
Hall-Traviss FC
Rohsenow Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5


Data of Wright, Series 2
Hall-Traviss FC
Mikic Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^5
10^4
10^3
10^3
10^4
10^5


Data of Wright, Series 2
Hall-Traviss FC
Thom Boiling
H, PREDICTED BTU/(HR-SQFT-DEGF)
H, EXPERIMENTAL BTU/(HR-SQFT-DEGF)
10^3
10^4
10^5
S

Appendix IV

DATA REDUCTION PROGRAM AND SAMPLE OUTPUT

A data reduction computer program was written to expedite the analysis of the large number of data points. The program requires the input of local conditions of mass flow rate, heat flux, vapor quality, saturation temperature, and experimental heat transfer coefficient. For each of the three proposed as well as the Chen correlation, the program uses the heat flux as specified, and predicts the resulting wall superheat using an iterative trial and error method, superposing the forced convection and boiling components.

For each data point, the program outputs the mass velocity, heat flux, saturation pressure, saturation temperature, quality, experimental wall superheat, experimental heat transfer coefficient, Martinelli parameter, liquid Reynolds number, Hall-Traviss forced convection heat transfer coefficient, incipient boiling heat flux, and the predicted heat transfer coefficients and resulting deviations for the Chen, Hall-Traviss/Rohsenow, Hall-Traviss/Mikic, and Hall-Traviss/Thom correlations.

Water property values are determined using a linear interpolation table search routine. The empirical Chen

F and S factors are determined in a similar manner.

The job control language, input/output device numbers, and plotting routine are unique to the MIT Interdata Joint Computing Facility, but the remainder of the program is standard Fortran IV.

The organization of a sample input deck is shown below:

```
// XEQ 3
BC/1000/
LC/AREA 1/1000
LC/AREA 2/1000
```

CARD 1	X-axis label for scatter plot, col.1-40 Y-axis label for scatter plot, col.41-80 FORMAT 40A2
CARDS 2-5	25 values of saturation temperature (^{o}F), FORMAT 8F10.6
CARDS 6-9	25 corresponding values of liquid density (lbm/ft^3), FORMAT 8F10.6
CARDS 10-13	" " " " " vapor density
CARDS 14-17	" " " " " latent heat (BTU/lbm), FORMAT 8F10.6
CARDS 18-21	" " " " " liquid specific heat (BTU/lbm-^{o}F), FORMAT 8F10.6
CARDS 22-25	" " " " " liquid surface tension (lbf/ft), FORMAT 8F10.6
CARDS 26-29	" " " " " liquid viscosity, (lbm/hr-ft), FORMAT 8F10.6
CARDS 30-33	" " " " " vapor viscosity

CARDS 34-37	25 corresponding values of liquid thermal conductivity (BTU/hr-ft-^{o}F), FORMAT 8F10.6
CARDS 38-41	" " " " " Prandtl number
CARDS 42-45	" " " " " saturation pressure (psia), FORMAT 8F10.6
CARDS 46-49	28 values of $1/X_{tt}$ in the range 0.1 to 100 FORMAT 8F10.6
CARDS 50-53	28 corresponding values of Chen F-factor FORMAT 8F10.6
CARDS 54-56	21 values of Chen two-phase Reynolds number in the range 10^3 to 10^7, FORMAT 8F10.6
CARDS 56-58	21 corresponding values of Chen s-factor
CARD 59	Inside tube dimater (in.), maximum active cavity radius (ft.), C_{sf}, B_M, m, W, number of points in data set FORMAT 6E12.4,I8
CARD 60	Name identifier of data set (col.1-80) FORMAT 40A2
CARD 61	Fluid identification (col.1-80) FORMAT 40A2
CARD 62	Flow orientation (col.1-80) FORMAT 40A2
CARD 63-62+#pts.	Mass flow rate (lbm/hr), heat flux (BTU/hr-ft^2), quality (decimal fraction), saturation temperature (^{o}F), experimental heat transfer coefficient (BTU/hr-ft^2-^{o}F) FORMAT 5F15.4
CARD 62+#pts.	Blank card if this is only data set or repeat with card 59 for batch runs of data sets; a blank card must follow the last data point of the last data set

The program listing and output from the calculations are provided in the following pages.

```
50     FORMAT(6F12.8,I8)
51     FORMAT(40A2)
100    FORMAT('1'//////  ,15X,'DATA OF:  ',40A2,/,15X,'TYPE OF FLUID:  ',
      140A2/,15X,'FLOW ORIENTATION:  ',40A2/,15X,'TUBE DIAMETER:',F9.4,'
      2IN.'/,15X,'MAX ASSUMED ACTIVE CAVITY SIZE:',F10.6,' FT.'/,15X,'NUM
      3BER OF DATA POINTS:  ',I3/,15X,'CSF=',F7.4/,15X,'B=',F10.7/,15X,'W
      4=',F6.3///)
101    FORMAT('1'/////,15X,'DATA OF:  ',40A2/)
102    FORMAT(
      5 15X,'KEY TO REDUCED DATA'//,15X,'FIRST ROW:   G(LBM/HR-FT**2), Q/
      6A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR'/,28
      7X,                                                                .
      8QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT
      9(BTU/HR-FT**2-DEGF),'/,28X,
      *'MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER'/,15X,
      1'SECOND ROW:  HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFIC
      2IENT(BTU/HR-FT**2-DEGF),'/,28X,
      3'INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDIC
      4TED BY CHEN,'/,28X,
      5'DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSEN
      6OW NB,'/,28X,
      7'DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC
      8 NB,'/,28X,
      9'DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM
      *NB,'/,28X,'DEVIATION OF H-T/T'/,'1'/////,15X,'DATA OF:  ',40A2/)
150    FORMAT(8F10.6)
160    FORMAT(5F15.4)
200    FORMAT(15X,F8.0,F10.0,F8.0,F8.1,F8.3,F7.1,F9.0,F8.3,F10.0/,15X,
      1F6.0,F9.0,F9.0,F8.4,F9.0,F8.4,F9.0,F8.4,F9.0,F8.4/)
300    FORMAT(//,15X,'AVERAGE DEVIATIONS FOR THE DATA OF:  ',40A2/,20X,'C
      1HEN CORRELATION:  ',F8.4/,20X,'HALL-TRAVISS FC/ROHSENOW NB:  ',
      2F8.4/,20X,'HALL-TRAVISS FC/MIKIC NB:  ',F8.4/,20X,'HALL-TRAVISS FC
      3/THOM NB:  ',F8.4)
```

```
USER=BASKERV 703 15422    JOINT COMPUTER FACILITY, MIT

      COMMON/AREA1/T(25),TRHOL(25),TRHOV(25),THFG(25),TSPECL(25),
     1TSIG(25),TVL(25),TVV(25),TPRL(25),TPRESS(25),TCONDL(25)
      COMMON/AREA2/AB1(28),FCHEN(28),AB2(21),SCHEN(21)
      COMMON FLOW,OONA,X,TSAT,HDATA,DIA,RMAX,RHOL,RHOV,HFG,SPECL,SIGMA,
     1VISCL,VISCV,CONDL,PRL,PRESS,VISCR,RHOR,REYL,XTT,DELSAT
      DIMENSION P(5,200)
      REAL XPOS(4),XSCL(4)
      INTEGER*2 XLAB(40),NAME(40),FLUID(40),ORIENT(40)
      INTEGER*4 R,O
      F1(Q,NN)= Q/FLOAT(NN)
      DATA XSCL/1000.,100000.,1000.,100000./
      DATA YPOS/200.,325.,485.,485./
      R=8
      O=5
      LOOK=18
      MOVE=0
      READ(R,51) XLAB
      READ(R,150)(T(J)       ,J=1,25)
      READ(R,150)(TRHOL(J)   ,J=1,25)
      READ(R,150)(TRHOV(J)    ,J=1,25)
      READ(R,150)(THFG(J)    ,J=1,25)
      READ(R,150) (TSPECL(J),J=1,25)
      READ(R,150)(TSIG(J)    ,J=1,25)
      READ(R,150)(TVL(J),    J=1,25)
      READ(R,150)(TVV(J)     ,J=1,25)
      READ(R,150)(TCONDL(J) ,J=1,25)
      READ(R,150)(TPRL(J)    ,J=1,25)
      READ(R,150)(TPRESS(J)   ,J=1,25)
      READ(R,150)(AB1(I),      I=1,28)
      READ(R,150)(FCHEN(I),    I=1,28)
      READ(R,150)(AB2(I),      I=1,21)
      READ(R,150)(SCHEN(I),    I=1,21)
500   READ(R,50) DIA,RMAX,CSF,B,XM,W1,NPTS
```

USER=BASKERV 703 15422   JOINT COMPUTER FACILITY, MIT

```
      IF(NPTS.LE.0) GO TO 2000
      READ(R,51) NAME
      READ(R,51) FLUID
      READ(R,51) ORIENT
      SUMC=0.
      SUMR=0.
      SUMM=0.
      SUMT=0.
      WRITE(O,100) NAME,FLUID,ORIENT,DIA,RMAX,NPTS,CSF,B,W1
      WRITE(O,102) NAME
      DO 1000  K=1,NPTS
      READ(R,160) FLOW,QONA,X,TSAT,HDATA
      CALL WATER
      G=FLOW*144./0.785/DIA**2
      Y=1.-X
      REYL=G*DIA/12.*Y/VISCL
      XTT=(VISCR)**0.1*(Y/X)**0.9/RHOR**0.5
      DELSAT=QONA/HDATA
      CALL TRAVIS(HFCT,F2)
      CALL CHEN(HMAC,HMIC,HCHEN,DEVC,SUMC,S,F)
      CALL BOIL(HFCT,DELTIB,RCRIT,Z,Z1,QONAIB)
      CALL ROSNOW(CSF,DELTIB,HFCT,Z,HBOILR,HPREDR,DEVR,SUMR)
      CALL MIKIC(B,XM,DELTIB,HFCT,Z,HBOILM,HPREDM,DEVM,SUMM)
      CALL THOM(W1,DELTIB,HFCT,Z,HBOILT,HPREDT,DEVT,SUMT)
      P(1,K)=HPREDR
      P(2,K)=HCHEN
      P(3,K)=HPREDM
      P(4,K)=HDATA
      P(5,K)=HPREDT
      WRITE(O,200) G,QONA,PRESS,TSAT,X,DELSAT,HDATA,XTT,REYL,HFCT,QONAIB
     1,HCHEN,DEVC,HPREDR,DEVR,HPREDM,DEVM,HPREDT,DEVT
      IF(FLOAT(K/12).EQ.FLOAT(K)/12.) WRITE(O,101)NAME
1000  CONTINUE
```

```
      AVDEVC=F1(SUMC,NPTS)
      AVDEVR=F1(SUMR,NPTS)
      AVDEVM=F1(SUMM,NPTS)
      AVDEVT=F1(SUMT,NPTS)
      WRITE(0,300) NAME,AVDEVC,AVDEVR,AVDEVM,AVDEVT
      CALL QPICTR(P,5,NPTS,QLABEL(1004),QPOS(XPOS),QXLAB(XLAB),QISCL(28)
     1,QX(4),QY(1),QMOVE(MOVE))
      MOVE=-1
      CALL QPICTR(P,5,NPTS,QMOVE(MOVE),QY(2))
      CALL QPICTR(P,5,NPTS,QMOVE(MOVE),QY(3))
      CALL QPICTR(P,5,NPTS,QMOVE(MOVE),QY(5))
      GO TO 500
 2000 CONTINUE
      STOP
      END
PROGRAM  *MAIN* HAS    NO ERRORS
```

```
USER=HASKERV 703 15422    JOINT COMPUTER FACILITY, MIT

      SUBROUTINE WATER
      COMMON/AREA1/T(25),TRHOL(25),TRHOV(25),THFG(25),TSPECL(25),
     1TSIG(25),TVL(25),TVV(25),TPRL(25),TPRESS(25),TCONDL(25)
      COMMON FLOW,QONA,X,TSAT,HDATA,DIA,RMAX,RHOL,RHOV,HFG,SPECL,SIGMA,
     1VISCL,VISCV,CONDL,PRL,PRESS,VISCR,RHOR,REYL,XTT,DELSAT
      FIT(A,B,C,D,E) = A+(B-A)*(C-D)/(E-D)
      DO 1 I=1,25
      IF(TSAT-T(I)) 2,2,1
1     CONTINUE
2     RHOL=FIT(TRHOL(I-1),TRHOL(I),TSAT,T(I-1),T(I))
      RHOV=FIT(TRHOV(I-1),TRHOV(I),TSAT,T(I-1),T(I))
      HFG=FIT(THFG(I-1),THFG(I),TSAT,T(I-1),T(I))
      SPECL=FIT(TSPECL(I-1),TSPECL(I),TSAT,T(I-1),T(I))
      CONDL=FIT(TCONDL(I-1),TCONDL(I),TSAT,T(I-1),T(I))
      SIGMA=FIT(TSIG(I-1),TSIG(I),TSAT,T(I-1),T(I))
      VISCL=FIT(TVL(I-1),TVL(I),TSAT,T(I-1),T(I))
      VISCV=FIT(TVV(I-1),TVV(I),TSAT,T(I-1),T(I))
      PRL=FIT(TPRL(I-1),TPRL(I),TSAT,T(I-1),T(I))
      PRESS=FIT(TPRESS(I-1),TPRESS(I),TSAT,T(I-1),T(I))
      VISCR=VISCL/VISCV
      RHOR=RHOL/RHOV
      RETURN
      END
PROGRAM  WATER  HAS    NO ERRORS
```

```
USER=BASKERV 703 15422    JOINT COMPUTER FACILITY, MIT

      SUBROUTINE TRAVIS(HFCT,F2)
      COMMON FLOW,CONA,X,TSAT,HDATA,DIA,PMAX,RHOL,RHOV,HFG,SPECL,SIGMA,
     1VISCL,VISCV,CONDL,PRL,PRESS,VISCR,RHOR,REYL,XTT,DELSAT
      FXTT=0.15/XTT+0.3/XTT**0.32
      F2=5.0*PRL+5.0*ALOG(1.0+5.0*PRL)+2.5*ALOG(0.00313*REYL**0.812)
      HFCT=FXTT*PRL*REYL**0.9/F2*CONDL/DIA*12.
      RETURN
      END
PROGRAM  TRAVIS HAS     NO ERRORS
```

```
USER=BASKERV 703 15422     JOINT COMPUTER FACILITY, MIT

      SUBROUTINE BOIL(HFC,DELTIB,RCRIT,Z,Z1,QONAIB)
      COMMON FLOW,QONA,X,TSAT,HDATA,DIA,RMAX,RHOL,RHOV,HFG,SPECL,SIGMA,
     1VISCL,VISCV,CONDL,PRL,PRESS,VISCR,RHOR,REYL,XTT,DELSAT
      Z=1.0
      B=2.0*SIGMA*(TSAT+459.69)/RHOL*(RHOR-1.0)/HFG/778.
      DELTIB=4.0*B*HFC/CONDL
      RCRIT=SQRT(B*CONDL/HFC/DELTIB)
      IF(RCRIT.GT.RMAX)  RCRIT=RMAX
      QONAIB=B*CONDL/RCRIT**2/(CONDL/RCRIT-HFC)*HFC
      IF(QONAIB.GE.QONA) Z=0.
      DELTIB=QONAIB/HFC
      Z1=Z
      RETURN
      END
PROGRAM  BOIL   HAS    NO ERRORS
```

```
USER=BASKERV 703 15422    JOINT COMPUTER FACILITY, MIT

      SUBROUTINE CHEN(HMAC,HMIC,HCHEN,DEVC,SUM,S,F)
      COMMON/AREA2/AB1(28),FCHEN(28),AB2(21),SCHEN(21)
      COMMON FLOW,QONA,X,TSAT,HDATA,DIA,PMAX,RHOL,RHOV,HFG,SPECL,SIGMA,
     1VISCL,VISCV,CONDL,PRL,PRESS,VISCR,RHOR,REYL,XTT,DELSAT
      FIT(A,B,C,D,E) = A+(B-A)*(C-D)/(E-D)
      C1=1.0/XTT
      DO 1  I=1,28
      IF(C1-AB1(I)) 2,2,1
1     CONTINUE
2     F=FIT(FCHEN(I-1),FCHEN(I),C1,AB1(I-1),AB1(I))
      HMAC=0.276*REYL**0.8*PRL**0.4*F*CONDL/DIA
      C2=REYL*F**1.25
      DO 3  I=1,21
      IF(C2-AB2(I)) 4,4,3
3     CONTINUE
4     S=FIT(SCHEN(I-1),SCHEN(I),C2,AB2(I-1),AB2(I))
      DELTAT=QONA/HMAC
      FVAR=    25.6868*CONDL**0.79*SPECL**0.45*RHOL**1.24*HFG**0.51
     1             /SIGMA**0.5/VISCL**0.29/RHOV**0.24/(TSAT+459.69)
     2**0.75/(RHOR-1.0)**0.75*S
      DO 5 I=1,50
      HMIC=FVAR*DELTAT**0.99
      HCHEN=HMAC+HMIC
      DUM=QONA/HCHEN
      IF(ABS(DELTAT-DUM).LE.0.005*DELTAT) GO TO 6
      DELTAT=(DELTAT+DUM)/2.
5     CONTINUE
6     DEVC=(DELTAT-DELSAT)/DELSAT
      SUM=SUM+ABS(DEVC)
      RETURN
      END
PROGRAM  CHEN   HAS    NO ERRORS
```

```
USER=BASKERV 703 15422    JOINT COMPUTER FACILITY, MIT

      SUBROUTINE ROSNOW(CSF,DELTIB,HFC,Z,HBOILR,HPREDR,DEVR,SUM)
      COMMON FLOW,QONA,X,TSAT,HDATA,DIA,PMAX,RHOL,RHOV,HFG,SPECL,SIGMA,
     1VISCL,VISCV,CONDL,PRL,PRESS,VISCR,RHOR,REYL,XTT,DELSAT
      DELTAT=QONA/HFC
      PVAR=  (SPECL        /HFG/PRL**1.7/CSF)**3*VISCL*HFG/SQRT(SIGMA
     1/(RHOL-RHOV))*Z
      DO 1 I=1,50
      QONABR=PVAR*DELTAT**3*(1.0-(DELTIB/DELTAT)**3)
      HBOILR=QONABR/DELTAT
      HPREDR=HFC+HBOILR
      DUM =QONA/HPREDR
      IF(ABS(DELTAT-DUM).LE.0.005*DELTAT) GO TO 2
      DELTAT=(DELTAT+DUM)/2.
1     CONTINUE
2     DEVR=(DELTAT-DELSAT)/DELSAT
      SUM=SUM+ABS(DEVR)
      RETURN
      END
PROGRAM  ROSNOW HAS    NO ERRORS
```

```
USER=BASKERV 703 15422     JOINT COMPUTER FACILITY, MIT

      SUBROUTINE MIKIC(B,XM,DELTIB,HFC,Z,HBOILM,HPREDM,DEVM,SUM)
      COMMON FLOW,QONA,X,TSAT,HDATA,DIA,RMAX,RHOL,RHOV,HFG,SPECL,SIGMA,
     1VISCL,VISCV,CONDL,PRL,PRESS,VISCR,RHOR,REYL,XTT,DELSAT
      DELTAT=QONA/HFC
      PVAR=           HFG/SQRT(SIGMA/(RHOL-RHOV))*B*CONDL**0.5*RHOL**2.12
     15*SPECL**2.375*HFG**(XM-2.875)*RHOV**(XM-1.375)/      (RHOL-RHOV)
     2**1.125/SIGMA**(XM-1.375)/(TSAT+459.7)**(XM-1.875)*Z
      DO 1 I=1,50
      QONABM=PVAR*DELTAT**(XM+1.)*(1.0-(DELTIB/DELTAT)**(XM+1.))
      HBOILM=QONABM/DELTAT
      HPREDM=HFC+HBOILM
      DUM =QONA/HPREDM
      IF(ABS(DELTAT-DUM).LE.0.005*DELTAT) GO TO 2
      DELTAT=(DELTAT+DUM)/2.
1     CONTINUE
2     DEVM=(DELTAT-DELSAT)/DELSAT
      SUM=SUM+ABS(DEVM)
      RETURN
      END
PROGRAM  MIKIC  HAS     NO ERRORS
```

```
USER=BASKERV 703 15422     JOINT COMPUTER FACILITY, MIT

      SUBROUTINE THOM(W1,DELTIB,HFC,Z,HBOILT,HPREDT,DEVT,SUM)
      COMMON FLOW,QONA,X,TSAT,HDATA,DIA,RMAX,RHOL,RHOV,HFG,SPECL,SIGMA,
     1VISCL,VISCV,CONDL,PRL,PRESS,VISCR,RHOR,REYL,XTT,DELSAT
      DELTAT=QONA/HFC
      DO 1 I=1,50
      QONABT=(DELTAT/W1*EXP(PRESS/1260.))**2*(1.0-(DELTIB/DELTAT)**2)*Z
      HBOILT=QONABT/DELTAT
      HPREDT=HFC+HBOILT
      DUM =QONA/HPREDT
      IF(ABS(DELTAT-DUM).LE.0.005*DELTAT) GO TO 2
      DELTAT=(DELTAT+DUM)/2.
1     CONTINUE
2     DEVT=(DELTAT-DELSAT)/DELSAT
      SUM=SUM+ABS(DEVT)
      RETURN
      END
PROGRAM  THOM   HAS    NO ERRORS
```

```
DATA OF:  DENGLER
TYPE OF FLUID:  WATER
FLOW ORIENTATION:  VERTICAL UPFLOW
TUBE DIAMETER:   1.0000 IN.
MAX ASSUMED ACTIVE CAVITY SIZE:  0.000010 FT.
NUMBER OF DATA POINTS:  119
CSF= 0.0288
B= 0.0000213
W= 0.132


KEY TO REDUCED DATA

FIRST ROW:   G(LBM/HR-FT**2), Q/A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR
             QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
             MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER
SECOND ROW:  HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
             INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDICTED BY CHEN,
             DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSENOW NB,
             DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC NB,
             DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM NB,
             DEVIATION OF H-T/T
```

DATA OF: DENGLER

43659.	19000.	16.	214.7	0.104	14.7	1290.	0.244	4833.	
804.	14914.	1386.	-0.0666	854.	0.5155	962.	0.3473	958.	0.3512
43659.	27600.	15.	213.6	0.281	14.7	1880.	0.081	3854.	
1559.	30151.	1888.	-0.0009	1559.	0.2059	1559.	0.2059	1559.	0.2059
43659.	33500.	15.	212.6	0.410	13.3	2510.	0.048	3145.	
2067.	41349.	2244.	0.1215	2067.	0.2146	2067.	0.2146	2067.	0.2146
44209.	29600.	17.	218.7	0.059	24.1	1230.	0.441	5258.	
574.	9812.	1571.	-0.2154	851.	0.4486	1277.	-0.0410	1244.	-0.0159
44209.	36700.	16.	217.1	0.203	23.8	1540.	0.123	4413.	
1236.	22136.	1846.	-0.1530	1364.	0.1316	1689.	-0.0901	1672.	-0.0777
44209.	40800.	16.	216.0	0.363	24.0	1700.	0.059	3505.	
1870.	34792.	2212.	-0.2291	1909.	-0.1059	2042.	-0.1668	2040.	-0.1629
44209.	63800.	16.	215.3	0.580	23.2	2750.	0.026	2302.	
2696.	51969.	2680.	0.0290	2752.	0.0038	2974.	-0.0748	2958.	-0.0675
44025.	60600.	17.	219.3	0.109	28.5	2130.	0.243	4975.	
818.	13918.	2088.	0.0222	1333.	0.6005	2173.	-0.0157	2015.	0.0525
44025.	70500.	17.	217.9	0.401	27.6	2550.	0.052	3318.	
1987.	35761.	2516.	0.0167	2202.	0.1610	2830.	-0.1027	2754.	-0.0726
40907.	156100.	17.	218.1	0.315	44.6	3500.	0.073	3530.	
1568.	27803.	2955.	0.1874	2523.	0.3910	4240.	-0.1739	3656.	-0.0409
44759.	35800.	28.	247.2	0.208	19.8	1810.	0.153	5262.	
1132.	12144.	1936.	-0.0623	1439.	0.2606	1877.	-0.0343	1899.	-0.0460
44759.	35600.	28.	246.8	0.363	20.1	1770.	0.076	4223.	
1654.	18091.	2150.	-0.1741	1822.	-0.0259	2144.	-0.1730	2193.	-0.1889

DATA OF: DANGLF-

170043.	159100.	21.	230.3	0.382	29.2	5450.	0.062	14232.	
5439.	87457.	5358.	0.0199	5665.	-0.0341	6457.	-0.1534	6327.	-0.1362
172433.	67400.	27.	243.4	0.063	24.4	2760.	0.506	23477.	
1675.	19306.	2496.	0.1092	2136.	0.2947	2867.	-0.0374	2794.	-0.0097
172433.	99700.	26.	241.2	0.156	24.6	4020.	0.200	20891.	
2861.	35251.	3290.	0.2253	3257.	0.2383	4092.	-0.0151	3983.	0.0130
172433.	143000.	21.	230.9	0.407	40.1	3570.	0.056	13891.	
5740.	92039.	5591.	-0.3584	5890.	-0.3923	6460.	-0.4449	6391.	-0.4402
172433.	94400.	24.	237.3	0.266	26.4	3570.	0.106	17787.	
4115.	56021.	4198.	-0.1470	4272.	-0.1613	4761.	-0.2467	4749.	-0.2465
169682.	100000.	24.	237.9	0.057	30.5	3280.	0.534	22550.	
1591.	20014.	2721.	0.2086	2345.	0.4053	3446.	-0.0477	3176.	0.0359
169498.	151600.	25.	238.6	0.205	30.9	4910.	0.145	19047.	
3404.	44432.	3874.	0.2707	3999.	0.2316	5239.	-0.0610	4922.	0.0023
169682.	181500.	19.	225.2	0.400	31.1	5840.	0.055	13370.	
5731.	100063.	5613.	0.0433	5962.	-0.0166	6868.	-0.1462	6673.	-0.1224
169498.	112000.	26.	241.8	0.057	32.4	3460.	0.550	23020.	
1572.	18530.	2942.	0.2207	2497.	0.3900	3689.	-0.0607	3339.	0.0404
169682.	155000.	23.	234.5	0.205	33.3	4650.	0.140	18652.	
3470.	48734.	3906.	0.1934	4021.	0.1602	5286.	-0.1188	4962.	-0.0588
169498.	163800.	22.	232.3	0.386	30.7	5340.	0.062	14242.	
5403.	83504.	5343.	0.0023	5665.	-0.0530	6542.	-0.1796	6381.	-0.1604
43659.	14400.	16.	216.6	0.031	14.1	1020.	0.793	5283.	
406.	7191.	1147.	-0.1092	534.	0.9116	709.	0.4353	750.	0.4186

DATA OF: DENGLER

170599.	25200.	22.	232.9	0.013	22.4	1170.	2.016	23115.	
797.	10732.	1600.	-0.2671	1012.	0.1578	1363.	-0.1431	1368.	-0.1471
170599.	41800.	21.	231.5	0.050	20.9	2000.	0.572	22086.	
1523.	21457.	2092.	-0.0407	1700.	0.1792	2110.	-0.0519	2108.	-0.0499
170599.	49000.	21.	229.9	0.102	20.5	2390.	0.282	20702.	
2292.	33986.	2594.	-0.0761	2384.	0.0060	2666.	-0.1027	2672.	-0.1039
170599.	76400.	20.	227.1	0.170	21.0	3640.	0.163	18809.	
3174.	50355.	3382.	0.0812	3293.	0.1093	3703.	-0.0166	3689.	-0.0094
170599.	95500.	18.	220.6	0.278	18.4	5190.	0.088	15741.	
4529.	83253.	4480.	0.1642	4569.	0.1407	4752.	0.0957	4740.	0.1004
171332.	40600.	24.	238.0	0.020	25.2	1610.	1.419	23686.	
955.	11799.	1918.	-0.1584	1326.	0.2153	1873.	-0.1388	1853.	-0.1282
171332.	62800.	24.	237.8	0.080	23.5	2670.	0.384	22211.	
1935.	24600.	2533.	0.0575	2237.	0.1969	2863.	-0.0670	2828.	-0.0543
171332.	61100.	23.	235.6	0.150	23.5	2600.	0.200	20280.	
2833.	38431.	3087.	-0.1557	2962.	-0.1188	3325.	-0.2160	3340.	-0.2179
171332.	104500.	22.	231.8	0.243	24.1	4340.	0.113	17702.	
3957.	59227.	4069.	0.0704	4141.	0.0526	4744.	-0.0819	4688.	-0.0722
171332.	134400.	13.	223.7	0.393	20.5	6550.	0.056	13536.	
5740.	103588.	5549.	0.1856	5823.	0.1286	6198.	0.0595	6156.	0.0676
170048.	39500.	25.	239.8	0.128	28.0	3551.	0.244	21123.	
2517.	31431.	3079.	0.1571	2985.	0.1930	3904.	-0.0894	3755.	-0.0510
170048.	90800.	24.	236.6	0.333	28.4	3200.	0.079	15880.	
4767.	66911.	4714.	-0.3179	4851.	-0.3377	5143.	-0.3756	5157.	-0.3769

DATA OF: DENGLER

273325.	31000.	20.	226.3	0.026	15.7	1980.	1.012	35193.	
1625.	25114.	1984.	0.0010	1675.	0.1846	1811.	0.0935	1816.	0.0903
273325.	36500.	19.	224.2	0.051	16.3	2240.	0.530	33860.	
2309.	37513.	2475.	-0.0925	2309.	-0.0300	2303.	-0.0300	2309.	-0.0300
273325.	64800.	17.	220.2	0.085	17.3	3740.	0.314	31887.	
3119.	55502.	3227.	0.1638	3159.	0.1871	3327.	0.1271	3321.	0.1304
273325.	92000.	14.	208.1	0.154	18.0	5101.	0.154	27456.	
4742.	110366.	4711.	0.0868	4742.	0.0756	4742.	0.0756	4742.	0.0756
276076.	52500.	26.	240.6	0.039	19.1	2750.	0.780	37960.	
1930.	23414.	2429.	0.1358	2164.	0.2745	2658.	0.0360	2664.	0.0339
276076.	54100.	23.	235.0	0.074	18.9	2860.	0.405	35437.	
2763.	37719.	2946.	-0.0269	2852.	0.0058	3127.	-0.0834	3146.	-0.0881
276076.	95300.	22.	233.5	0.132	20.9	4560.	0.224	33001.	
3910.	56623.	4036.	0.1338	4070.	0.1249	4590.	-0.0026	4560.	0.0021
276076.	129800.	18.	220.4	0.221	21.5	6030.	0.115	27453.	
5747.	109341.	5627.	0.0758	5799.	0.0444	6052.	-0.0021	6023.	0.0032
176102.	17300.	18.	221.9	0.025	9.9	1750.	1.012	22098.	
1125.	19451.	1493.	0.1759	1125.	0.5553	1125.	0.5553	1125.	0.5553
176102.	23600.	18.	220.4	0.048	12.0	1970.	0.544	21400.	
1575.	26780.	1861.	0.0620	1575.	0.2510	1575.	0.2510	1575.	0.2510
176102.	33900.	17.	218.7	0.080	12.3	2760.	0.329	20478.	
2110.	37524.	2328.	0.1989	2110.	0.3083	2110.	0.3083	2110.	0.3083
176102.	43900.	16.	216.2	0.126	11.4	3840.	0.204	19177.	
2807.	53336.	2926.	0.3173	2807.	0.3679	2807.	0.3679	2807.	0.3679

DATA OF: DENGLER

289834.	198000.	21.	229.2	0.193	27.0	7100.	0.144	31471.	
5284.	86121.	5491.	0.2972	5559.	0.2579	6873.	0.0373	6560.	0.0865
288917.	17000.	31.	252.2	0.023	11.6	1460.	1.393	42969.	
1512.	15025.	1780.	-0.1773	1533.	-0.0451	1578.	-0.0714	1597.	-0.0841
288917.	27000.	31.	251.3	0.038	12.3	2190.	0.868	42122.	
1923.	19615.	2195.	0.0007	1986.	0.1059	2123.	0.0344	2171.	0.0112
288917.	34100.	30.	250.0	0.059	11.5	2960.	0.566	40940.	
2418.	25582.	2599.	0.1417	2478.	0.1973	2619.	0.1335	2666.	0.1136
288000.	42800.	36.	260.6	0.014	15.2	2820.	2.342	45099.	
1194.	10277.	2099.	0.3471	1660.	0.7006	2149.	0.3122	2169.	0.3040
288000.	61800.	35.	259.4	0.051	17.0	3640.	0.701	43140.	
2172.	19538.	2688.	0.3587	2564.	0.4240	3112.	0.1737	3128.	0.1685
288000.	56200.	34.	257.9	0.091	14.6	3850.	0.396	40985.	
2975.	28040.	3185.	0.2146	3160.	0.2213	3508.	0.0996	3586.	0.0771
288000.	96500.	33.	255.3	0.144	19.9	4850.	0.243	38112.	
3922.	39468.	4138.	0.1765	4230.	0.1497	4822.	0.0076	4830.	0.0087
288000.	110000.	30.	249.8	0.218	21.0	5240.	0.148	33882.	
5268.	59754.	5368.	-0.0192	5403.	-0.0266	5885.	-0.1077	5908.	-0.1101
287083.	17500.	13.	207.2	0.024	11.1	1580.	0.926	33084.	
1712.	37198.	1813.	-0.1261	1712.	-0.0771	1712.	-0.0771	1712.	-0.0771
287083.	32800.	13.	203.4	0.044	10.1	3240.	0.510	31652.	
2368.	56036.	2442.	0.3332	2368.	0.3682	2368.	0.3682	2368.	0.3682
287083.	56500.	10.	194.7	0.078	13.3	4260.	0.271	29010.	
3413.	99086.	3382.	0.2628	3413.	0.2480	3413.	0.2480	3413.	0.2480

DATA OF: DENGLER

1016255.	70000.	42.	269.9	0.036	13.2	5300.	1.050	162854.	
4999.	41339.	4873.	0.0926	5130.	0.0361	5350.	-0.0071	5461.	-0.0268
1016255.	106800.	37.	262.3	0.052	13.1	8170.	0.702	154360.	
6123.	58947.	5905.	0.3895	6302.	0.3003	6659.	0.2299	6737.	0.2166
1025427.	69300.	24.	237.0	0.032	9.7	7130.	0.912	139270.	
5206.	73502.	4863.	0.4711	5206.	0.3695	5206.	0.3695	5206.	0.3695
994242.	31000.	19.	223.5	0.016	6.5	4800.	1.546	127181.	
3798.	65035.	3448.	0.3970	3798.	0.2637	3798.	0.2637	3798.	0.2637
542981.	18900.	19.	223.9	0.015	6.3	3010.	1.646	69693.	
2235.	36416.	2194.	0.3781	2235.	0.3467	2235.	0.3467	2235.	0.3467
542981.	34100.	17.	218.4	0.030	6.0	4991.	0.831	66457.	
3138.	57724.	3014.	0.6604	3138.	0.5903	3138.	0.5903	3138.	0.5903
541147.	33400.	27.	243.2	0.025	8.0	4190.	1.203	76582.	
2687.	31916.	2725.	0.5444	2696.	0.5595	2722.	0.5416	2730.	0.5367
541147.	53400.	25.	239.3	0.038	12.7	4190.	0.792	73956.	
3323.	42766.	3300.	0.2743	3374.	0.2462	3535.	0.1880	3562.	0.1793
541147.	62600.	21.	229.4	0.073	13.2	6270.	0.391	67580.	
4875.	78279.	4722.	0.3333	4990.	0.2861	4949.	0.2694	4952.	0.2688
531975.	51000.	36.	261.2	0.022	16.7	3060.	1.554	82885.	
2393.	21077.	2676.	0.1469	2643.	0.1611	3032.	0.0106	3108.	-0.0119
531975.	53800.	35.	259.5	0.043	16.5	3260.	0.824	80398.	
3292.	30484.	3350.	-0.0228	3432.	-0.0463	3703.	-0.1179	3791.	-0.1376
531975.	99000.	33.	255.0	0.074	17.9	5530.	0.474	76039.	
4426.	45426.	4485.	0.2370	4681.	0.1841	5210.	0.0638	5238.	0.0601

DATA OF: DENSLEY

284331.	46400.	32.	253.4	0.033	20.4	2270.	1.007	42104.	
1761.	17255.	2345.	-0.0290	2052.	0.1092	2507.	-0.0926	2546.	-0.1063
284331.	70900.	31.	251.4	0.075	20.0	3550.	0.455	39878.	
2703.	28114.	3054.	0.1659	3006.	0.1846	3567.	-0.0004	3575.	-0.0034
284331.	69900.	29.	248.9	0.124	18.6	3750.	0.269	37289.	
3645.	40743.	3789.	-0.0068	3794.	-0.0076	4149.	-0.0948	4199.	-0.1046
284331.	122200.	27.	243.7	0.193	21.9	5590.	0.162	33398.	
4880.	61147.	5007.	0.1195	5121.	0.0967	5760.	-0.0277	5724.	-0.0200
284331.	163000.	22.	231.7	0.296	22.6	7210.	0.088	27307.	
6855.	111921.	6685.	0.0826	6986.	0.0366	7501.	-0.0347	7438.	-0.0287
275159.	72800.	30.	250.5	0.064	22.6	3220.	0.526	38879.	
2423.	25402.	2878.	0.1223	2793.	0.1566	3428.	-0.0577	3406.	-0.0510
275159.	68500.	29.	248.1	0.112	22.6	3030.	0.297	36456.	
3351.	37639.	3522.	-0.1361	3521.	-0.1355	3915.	-0.2248	3957.	-0.2324
275159.	121000.	27.	243.4	0.181	23.4	5171.	0.173	32746.	
4565.	56953.	4706.	0.1023	4833.	0.0724	5525.	-0.0627	5474.	-0.0518
275159.	165000.	22.	231.9	0.276	22.5	7350.	0.097	27205.	
6352.	101751.	6272.	0.1770	6529.	0.1290	7194.	0.0267	7095.	0.0385
293503.	93300.	30.	250.7	0.029	27.0	3450.	1.111	43064.	
1712.	17559.	2776.	0.2463	2508.	0.3825	3451.	-0.0006	3237.	0.0706
293503.	131300.	28.	247.0	0.104	26.8	4900.	0.318	38995.	
3394.	38798.	3756.	0.3082	3960.	0.2413	4985.	-0.0139	4766.	0.0297
293503.	124500.	25.	240.2	0.198	25.3	4920.	0.153	33605.	
5161.	68937.	5280.	-0.0659	5356.	-0.0782	5948.	-0.1714	5917.	-0.1659

DATA OF: DENGLER

531975.	64700.	37.	261.7	0.012	18.4	3520.	2.716	83949.	
1848.	15918.	2561.	0.3787	2383.	0.4805	2999.	0.1756	2972.	0.1900
531975.	98700.	35.	259.0	0.046	19.7	5020.	0.770	79941.	
3409.	31915.	3625.	0.3883	3851.	0.3079	4543.	0.1063	4501.	0.1174
531975.	92800.	32.	253.6	0.087	21.7	4270.	0.400	74449.	
4864.	51742.	4847.	-0.1168	5036.	-0.1491	5432.	-0.2122	5486.	-0.2193
528306.	148000.	31.	251.7	0.036	21.5	6890.	0.916	77335.	
3067.	32041.	3565.	0.9387	3906.	0.7682	5101.	0.3526	4741.	0.4557
528306.	179500.	26.	240.8	0.108	24.0	7480.	0.292	67499.	
5733.	77115.	5759.	0.3027	6091.	0.2310	7068.	0.0600	6885.	0.0912
280662.	17000.	16.	221.0	0.025	10.6	1610.	1.006	35053.	
1653.	27873.	1803.	-0.1046	1653.	-0.0261	1653.	-0.0261	1653.	-0.0261
280662.	28600.	17.	219.3	0.042	10.5	2730.	0.612	34103.	
2158.	38018.	2286.	0.1973	2158.	0.2650	2158.	0.2650	2158.	0.2650
280662.	40300.	16.	215.8	0.068	9.6	4201.	0.375	32518.	
2848.	54582.	2887.	0.4606	2848.	0.4752	2848.	0.4752	2848.	0.4752
284331.	34900.	24.	236.5	0.029	15.4	2260.	0.995	38633.	
1727.	22337.	2125.	0.0669	1831.	0.2404	2087.	0.0838	2112.	0.0718
284331.	39400.	23.	234.5	0.055	16.1	2440.	0.537	37199.	
2408.	32863.	2586.	-0.0540	2448.	0.0001	2576.	-0.0482	2592.	-0.0541
284331.	69100.	21.	231.5	0.094	17.1	4030.	0.311	35105.	
3295.	48694.	3408.	0.1873	3388.	0.1927	3706.	0.0899	3710.	0.0900
284331.	93500.	19.	223.4	0.152	17.5	4780.	0.178	31326.	
4549.	79595.	4530.	0.0597	4562.	0.0508	4619.	0.0366	4618.	0.0368

DATA OF: DENGLER

1001580.	7200.	26.	241.8	0.015	1.8	3930.	1.903	142088.	
3561.	44299.	3158.	0.2477	3561.	0.1035	3561.	0.1035	3561.	0.1035
1001580.	35800.	22.	232.0	0.028	6.0	5970.	0.989	133016.	
4862.	74396.	4479.	0.3385	4862.	0.2279	4862.	0.2279	4862.	0.2279
1014420.	39200.	32.	253.2	0.017	9.4	4150.	1.854	152549.	
3702.	38360.	3454.	0.2049	3706.	0.1211	3720.	0.1211	3724.	0.1170
1014420.	35800.	22.	232.0	0.028	6.0	5970.	0.989	134721.	
4913.	75297.	4523.	0.3253	4913.	0.2150	4913.	0.2150	4913.	0.2150
1014420.	78000.	26.	242.7	0.040	10.8	7210.	0.774	140958.	
5672.	73383.	5327.	0.3580	5686.	0.2710	5734.	0.2634	5741.	0.2583
1008917.	118400.	30.	250.1	0.052	14.8	7990.	0.639	144100.	
6322.	74559.	6048.	0.3264	6464.	0.2391	6840.	0.1705	6876.	0.1650
1008917.	73400.	37.	261.5	0.022	14.6	5040.	1.557	157440.	
4048.	37142.	3928.	0.2877	4240.	0.1941	4596.	0.0993	4680.	0.0807
1008917.	99500.	36.	260.3	0.012	21.0	4740.	2.689	158067.	
3135.	28556.	3293.	0.4437	3654.	0.3013	4400.	0.0825	4319.	0.0994
1008917.	150000.	30.	249.6	0.052	18.5	8000.	0.637	143749.	
6333.	75395.	6108.	0.3162	6588.	0.2192	7218.	0.1110	7187.	0.1173
999745.	23900.	38.	263.7	0.012	4.3	5520.	2.753	159421.	
3093.	26765.	2840.	0.9503	3093.	0.7845	3093.	0.7845	3093.	0.7845
999745.	43400.	34.	257.5	0.023	4.7	9250.	1.452	152685.	
4136.	40438.	3893.	1.3865	4150.	1.2367	4183.	1.2163	4203.	1.2065
1016255.	36100.	45.	273.7	0.013	11.3	3190.	2.761	169640.	
3167.	23416.	3001.	0.0677	3252.	-0.0163	3381.	-0.0519	3483.	-0.0821

DATA OF: DENGLER

44759.	55000.	28.	246.4	0.550	19.9	2760.	0.038	2976.	
2255.	25214.	2559.	0.0822	2481.	0.1155	2941.	-0.0586	2966.	-0.0675
44392.	120200.	29.	247.4	0.210	30.6	3930.	0.151	5212.	
1131.	12096.	2911.	0.3529	2432.	0.6149	3679.	0.0665	3203.	0.2278
44392.	52600.	29.	249.2	0.107	22.2	2370.	0.314	5946.	
741.	7506.	2195.	0.0818	1457.	0.6266	2144.	0.1082	2045.	0.1612
44392.	70000.	29.	248.5	0.363	23.2	3011.	0.077	4227.	
1632.	17370.	2527.	0.1950	2182.	0.3818	2930.	0.0277	2842.	0.0630
44209.	30800.	10.	194.0	0.061	21.5	1430.	0.341	4531.	
635.	17369.	1457.	-0.0164	775.	0.8491	946.	0.4342	745.	0.6175
44209.	40800.	10.	191.5	0.212	22.4	1820.	0.093	3737.	
1426.	41556.	1874.	-0.0256	1426.	0.2764	1426.	0.2764	1426.	0.2764
44209.	50500.	9.	189.5	0.401	23.1	2190.	0.040	2802.	
2294.	70905.	2398.	-0.0841	2294.	-0.0453	2294.	-0.0453	2294.	-0.0453
44209.	74400.	9.	185.6	0.654	21.4	3470.	0.015	1577.	
3480.	119635.	3011.	0.1576	3480.	-0.0029	3480.	-0.0029	3480.	-0.0029
45493.	64800.	11.	195.9	0.130	31.2	2080.	0.164	4368.	
1029.	27274.	1994.	0.0458	1313.	0.5855	2005.	0.0425	1873.	0.1140
45493.	92800.	10.	192.4	0.435	33.4	2780.	0.036	2775.	
2471.	72922.	2697.	0.0339	2549.	0.0936	2911.	-0.0415	2835.	-0.0173
45676.	159400.	10.	190.6	0.295	43.9	3631.	0.062	3433.	
1862.	55789.	2825.	0.2893	2353.	0.5457	3882.	-0.0677	3435.	0.0557

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DATA OF:  SCHROCK AND GROSSMAN, SERIES 'A'
TYPE OF FLUID:  WATER
FLOW ORIENTATION:  VERTICAL UPFLOW
TUBE DIAMETER:   0.1162 IN.
MAX ASSUMED ACTIVE CAVITY SIZE:  0.000010 FT.
NUMBER OF DATA POINTS:  160
CSF= 0.0288
B= 0.0000213
W= 0.132


KEY TO REDUCED DATA

FIRST ROW:    G(LBM/HR-FT**2), Q/A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR
              QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
              MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER
SECOND ROW:   HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
              INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDICTED BY CHEN,
              DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSENOW NB,
              DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC NB,
              DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM NB,
              DEVIATION OF H-T/T
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DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

2117869.	97100.	63.	304.0	0.013	12.2	7960.	3.309	46875.	
8175.	44976.	8275.	-0.0357	8384.	-0.0479	8536.	-0.0634	8712.	-0.0837
2117869.	97100.	60.	301.0	0.022	9.6	10100.	2.058	45915.	
10073.	61628.	10015.	0.0121	10184.	-0.0056	10275.	-0.0125	10411.	-0.0265
2117869.	97100.	59.	300.0	0.025	7.8	12500.	1.785	45551.	
10748.	68195.	10716.	0.1699	10833.	0.1584	10905.	0.1502	11018.	0.1375
2117869.	97100.	58.	297.0	0.031	7.8	12500.	1.457	44701.	
11796.	80958.	11730.	0.0709	11839.	0.0597	11880.	0.0558	11946.	0.0494
2117869.	97100.	57.	295.0	0.034	9.1	10700.	1.324	44185.	
12332.	88627.	12261.	-0.1236	12353.	-0.1323	12376.	-0.1323	12411.	-0.1352
2117869.	97100.	56.	293.0	0.039	7.2	13500.	1.154	43592.	
13164.	100417.	13208.	0.0256	13164.	0.0255	13164.	0.0255	13164.	0.0255
2117869.	97100.	56.	292.0	0.040	6.8	14300.	1.104	43335.	
13448.	105217.	13533.	0.0501	13448.	0.0633	13448.	0.0633	13448.	0.0633
2117869.	97100.	55.	289.0	0.045	5.5	17700.	0.974	42582.	
14281.	120713.	14140.	0.2551	14281.	0.2394	14281.	0.2394	14281.	0.2394
2117869.	97100.	54.	287.0	0.047	5.1	19000.	0.914	42123.	
14726.	130710.	14526.	0.3112	14726.	0.2902	14726.	0.2902	14726.	0.2902
2168272.	190000.	90.	314.0	0.022	15.3	12400.	2.258	49441.	
9939.	50220.	10545.	0.1789	10596.	0.1733	10907.	0.1405	10976.	0.1348
2168272.	190000.	78.	313.0	0.026	9.9	19200.	1.909	49037.	
10725.	56422.	11263.	0.7078	11289.	0.7049	11573.	0.6633	11677.	0.6509
2168272.	190000.	75.	311.0	0.034	12.4	15300.	1.466	48252.	
12125.	68896.	12578.	0.2212	12555.	0.2232	12796.	0.1985	12936.	0.1865

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

2168272.	190000.	72.	309.0	0.038	13.1	14500.	1.308	47688.	
12794.	76635.	13204.	0.1019	13164.	0.1049	13392.	0.0877	13535.	0.0743
2168272.	190000.	68.	307.0	0.046	10.5	18100.	1.081	46936.	
14035.	90716.	14503.	0.2513	14323.	0.2698	14514.	0.2515	14662.	0.2404
2168272.	190000.	63.	304.0	0.049	10.0	19000.	0.987	46234.	
14652.	101589.	14927.	0.2791	14901.	0.2800	15077.	0.2640	15215.	0.2539
2168272.	190000.	63.	304.0	0.056	8.0	23800.	0.878	45918.	
15559.	111818.	15716.	0.5207	15760.	0.5148	15909.	0.4997	16038.	0.4890
2168272.	190000.	59.	299.0	0.059	7.9	24100.	0.807	44830.	
16193.	128158.	16236.	0.4897	16337.	0.4819	16467.	0.4694	16569.	0.4583
2168272.	190000.	57.	295.0	0.066	7.2	26400.	0.707	43738.	
17274.	151496.	17220.	0.5374	17361.	0.5244	17449.	0.5204	17514.	0.5122
1476762.	403000.	139.	352.0	0.019	22.5	17900.	3.187	38522.	
6477.	17631.	10748.	0.6699	11180.	0.6043	11328.	0.5830	9506.	0.8888
1476762.	403000.	130.	347.0	0.097	25.2	16000.	0.690	34912.	
13309.	48765.	15104.	0.0620	15576.	0.0307	15762.	0.0184	15154.	0.0584
1476762.	403000.	117.	339.0	0.148	19.8	20400.	0.418	32104.	
17003.	80915.	18206.	0.1239	18445.	0.1093	18677.	0.0958	18447.	0.1103
1476762.	403000.	111.	335.0	0.170	19.6	20600.	0.352	30841.	
18552.	99817.	19598.	0.0537	19733.	0.0467	19978.	0.0341	19849.	0.0414
1476762.	403000.	109.	334.0	0.180	18.4	21900.	0.329	30360.	
19206.	108026.	20222.	0.0979	20301.	0.0814	20542.	0.0690	20447.	0.0745
1476762.	403000.	101.	328.0	0.199	19.1	21100.	0.283	29032.	
20707.	135650.	21691.	-0.0239	21581.	-0.0181	21834.	-0.0313	21800.	-0.0295

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

1476762.	403000.	97.	325.0	0.205	18.0	21700.	0.269	28515.	
21281.	149290.	22261.	-0.0222	22071.	-0.0130	22335.	-0.0237	22311.	-0.0250
1476762.	403000.	91.	321.0	0.219	16.1	25000.	0.242	27629.	
22449.	175933.	23407.	0.0707	23105.	0.0854	23359.	0.0747	23363.	0.0748
1476762.	403000.	88.	319.0	0.224	15.4	26200.	0.233	27250.	
22914.	188336.	23814.	0.1055	23513.	0.1175	23765.	0.1067	23775.	0.1066
1476762.	403000.	81.	315.0	0.236	11.5	35100.	0.214	26406.	
23957.	216645.	24748.	0.4242	24443.	0.4429	24684.	0.4265	24700.	0.4259
1469561.	100000.	58.	296.0	0.017	29.3	3410.	2.499	31327.	
6822.	40247.	7426.	-0.5395	7100.	-0.5177	7340.	-0.5341	7500.	-0.5435
1469561.	100000.	57.	294.0	0.030	15.8	6330.	1.477	30655.	
6690.	55918.	9074.	-0.2993	8843.	-0.2812	8992.	-0.2935	9142.	-0.3060
1469561.	100000.	56.	292.0	0.036	13.1	7630.	1.217	30195.	
9531.	64894.	9883.	-0.2252	9639.	-0.2063	9753.	-0.2158	9882.	-0.2250
1469561.	100000.	55.	290.0	0.046	11.2	8930.	0.963	29643.	
10695.	76042.	10922.	-0.1801	10756.	-0.1675	10825.	-0.1727	10910.	-0.1778
1469561.	100000.	55.	289.0	0.047	11.3	8850.	0.928	29473.	
10892.	81246.	11086.	-0.1996	10943.	-0.1875	11003.	-0.1917	11075.	-0.1979
1469561.	100000.	54.	287.0	0.051	9.9	10100.	0.855	29121.	
11340.	88652.	11475.	-0.1155	11370.	-0.1094	11407.	-0.1120	11453.	-0.1139
1469561.	100000.	54.	287.0	0.052	8.7	11500.	0.831	29075.	
11503.	90444.	11624.	-0.0060	11528.	-0.0003	11560.	-0.0003	11598.	-0.0045
1469561.	100000.	52.	283.0	0.056	10.6	9400.	0.759	28475.	
12017.	102402.	12071.	-0.2180	12017.	-0.2177	12017.	-0.2177	12017.	-0.2177

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

1469561.	260000.	109.	334.0	0.012	29.6	8790.	4.414	36398.	
5538.	18568.	8838.	-0.0027	8322.	0.0615	8709.	0.0132	7798.	0.1307
1469561.	260000.	108.	333.0	0.030	23.0	11300.	1.889	35600.	
8012.	29351.	10113.	0.1210	9929.	0.1414	10271.	0.1029	9791.	0.1575
1469561.	260000.	104.	330.0	0.064	24.1	10800.	0.917	33999.	
11304.	48113.	12655.	-0.1445	12464.	-0.1307	12746.	-0.1498	12639.	-0.1436
1469561.	260000.	95.	324.0	0.098	18.3	14200.	0.581	32084.	
14201.	73172.	15126.	-0.0580	14929.	-0.0467	15173.	-0.0616	15240.	-0.0650
1469561.	260000.	90.	320.0	0.114	17.2	15100.	0.485	31085.	
15572.	89952.	16401.	-0.0770	16151.	-0.0614	16375.	-0.0758	16480.	-0.0811
1469561.	260000.	86.	318.0	0.121	16.6	15700.	0.451	30594.	
16166.	98186.	16897.	-0.0664	16681.	-0.0556	16906.	-0.0671	17016.	-0.0749
1469561.	260000.	78.	313.0	0.133	15.5	16800.	0.397	29587.	
17279.	117610.	17855.	-0.0555	17679.	-0.0473	17897.	-0.0578	18014.	-0.0631
1469561.	260000.	75.	311.0	0.137	15.4	16900.	0.380	29222.	
17680.	125920.	18215.	-0.0689	18044.	-0.0589	18254.	-0.0710	18368.	-0.0760
1469561.	260000.	68.	307.0	0.147	14.0	18600.	0.343	28430.	
18681.	147515.	19143.	-0.0255	18962.	-0.0156	19151.	-0.0261	19253.	-0.0307
1469561.	260000.	65.	305.0	0.152	13.4	19400.	0.327	28062.	
19154.	159363.	19596.	-0.0073	19398.	0.0031	19573.	-0.0065	19666.	-0.0106
1469561.	260000.	59.	300.0	0.161	12.0	21700.	0.297	27212.	
20151.	189288.	20574.	0.0596	20313.	0.0725	20450.	0.0648	20516.	0.0622
1519964.	465000.	160.	363.0	0.022	23.2	20000.	3.048	40911.	
6808.	16237.	11576.	0.7323	12529.	0.5980	12437.	0.6099	10185.	0.9697

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

1519964.	465000.	156.	361.0	0.052	22.9	20300.	1.338	39400.	
9855.	26646.	13088.	0.5562	14200.	0.4312	14157.	0.4356	12567.	0.6204
1519964.	465000.	147.	357.0	0.110	23.2	20000.	0.634	36575.	
14158.	47365.	16118.	0.2439	17040.	0.1775	17069.	0.1754	16215.	0.2366
1519964.	465000.	134.	349.0	0.166	20.3	22900.	0.394	33396.	
17935.	77995.	19304.	0.1900	19838.	0.1581	19979.	0.1501	19571.	0.1751
1519964.	465000.	127.	345.0	0.190	19.4	24000.	0.332	32019.	
19555.	96374.	20771.	0.1583	21136.	0.1389	21311.	0.1297	21035.	0.1452
1519964.	465000.	123.	343.0	0.202	19.9	23400.	0.306	31343.	
20373.	107961.	21568.	0.0897	21813.	0.0758	21999.	0.0668	21777.	0.0782
1519964.	465000.	113.	337.0	0.223	17.4	26700.	0.263	29931.	
22013.	136677.	23197.	0.1548	23172.	0.1549	23392.	0.1443	23259.	0.1512
1519964.	465000.	111.	335.0	0.230	17.4	26700.	0.251	29448.	
22541.	146857.	23749.	0.1277	23622.	0.1357	23847.	0.1224	23737.	0.1279
1519964.	465000.	105.	331.0	0.244	14.3	32500.	0.228	28503.	
23625.	169722.	24715.	0.3184	24552.	0.3291	24796.	0.3171	24718.	0.3180
1519964.	465000.	101.	328.0	0.251	14.9	31200.	0.216	27942.	
24269.	186324.	25289.	0.2398	25103.	0.2474	25353.	0.2361	25297.	0.2391
1519964.	465000.	92.	322.0	0.263	13.0	35800.	0.197	26928.	
25523.	224107.	26424.	0.3605	26189.	0.3709	26440.	0.3590	26409.	0.3608
986863.	108000.	54.	287.0	0.019	31.7	3410.	2.101	20207.	
5297.	34144.	6473.	-0.4715	5733.	-0.4035	6155.	-0.4442	6233.	-0.4517
986863.	108000.	53.	285.0	0.040	21.0	5140.	1.058	19620.	
7359.	52103.	8171.	-0.3693	7579.	-0.3196	7836.	-0.3424	7976.	-0.3534

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

986863.	108000.	51.	282.0	0.060	12.9	8400.	0.706	18951.	
9042.	70553.	9501.	-0.1124	9157.	-0.0799	9312.	-0.0952	9429.	-0.1054
986863.	108000.	49.	280.0	0.069	11.0	9860.	0.609	18592.	
9762.	80210.	10154.	-0.0258	9841.	0.0059	9954.	-0.0051	10043.	-0.0155
986863.	108000.	49.	279.0	0.073	11.0	9860.	0.573	18425.	
10080.	84912.	10455.	-0.0540	10143.	-0.0249	10237.	-0.0334	10312.	-0.0416
986863.	108000.	47.	276.0	0.080	9.5	11400.	0.513	18032.	
10670.	95831.	11025.	0.0367	10702.	0.0684	10753.	0.0641	10793.	0.0589
986863.	108000.	46.	275.0	0.083	9.5	11400.	0.492	17891.	
10916.	100376.	11257.	0.0152	10935.	0.0443	10970.	0.0443	10995.	0.0404
986863.	108000.	44.	273.0	0.088	8.8	12300.	0.458	17631.	
11339.	109133.	11619.	0.0636	11339.	0.0847	11339.	0.0847	11339.	0.0847
986863.	108000.	44.	272.0	0.091	8.5	12700.	0.439	17493.	
11538.	114297.	11836.	0.0777	11588.	0.0960	11588.	0.0960	11588.	0.0960
986863.	108000.	42.	270.0	0.097	7.8	13900.	0.406	17221.	
12089.	125379.	12281.	0.1362	12089.	0.1498	12089.	0.1498	12089.	0.1498
918472.	209000.	115.	338.0	0.016	23.5	8880.	3.442	22981.	
4238.	13016.	7861.	0.1324	6955.	0.2806	7242.	0.2289	6454.	0.3799
918391.	209000.	115.	338.0	0.037	24.4	8560.	1.623	22500.	
5928.	19128.	8684.	-0.0112	7984.	0.0742	8242.	0.0402	7761.	0.1063
918391.	209000.	112.	336.0	0.077	20.7	10100.	0.794	21406.	
8372.	29874.	10184.	-0.0052	9720.	0.0426	9948.	0.0185	9798.	0.0336
918391.	209000.	109.	334.0	0.114	15.3	13700.	0.532	20400.	
10258.	39967.	11721.	0.1718	11234.	0.2234	11435.	0.2020	11454.	0.2021

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

918472.	209000.	108.	333.0	0.131	14.0	14900.	0.458	19939.	
11069.	44932.	12411.	0.2065	11920.	0.2536	12111.	0.2342	12178.	0.2290
918391.	209000.	106.	332.0	0.138	14.4	14500.	0.432	19707.	
11413.	47504.	12686.	0.1484	12211.	0.1908	12400.	0.1730	12485.	0.1663
918472.	209000.	105.	331.0	0.152	14.4	14500.	0.387	19319.	
12064.	52081.	13232.	0.1004	12778.	0.1376	12959.	0.1221	13073.	0.1135
918472.	209000.	104.	330.0	0.157	13.8	15100.	0.372	19138.	
12316.	54378.	13444.	0.1277	12996.	0.1647	13176.	0.1492	13300.	0.1397
918391.	209000.	102.	329.0	0.165	11.8	17700.	0.350	18888.	
12697.	57625.	13774.	0.2898	13335.	0.3340	13509.	0.3137	13645.	0.3019
918391.	209000.	102.	329.0	0.170	11.3	18500.	0.339	18775.	
12911.	59066.	13968.	0.3293	13529.	0.3740	13699.	0.3539	13840.	0.3413
918472.	209000.	101.	328.0	0.177	12.2	17100.	0.323	18553.	
13249.	62230.	14275.	0.2019	13830.	0.2420	13997.	0.2246	14147.	0.2127
954488.	292000.	108.	333.0	0.023	28.3	10300.	2.457	23301.	
5034.	16843.	8970.	0.1512	8409.	0.2281	8863.	0.1641	7629.	0.3542
954488.	292000.	106.	332.0	0.051	27.3	10700.	1.146	22541.	
7176.	25942.	10084.	0.0645	9681.	0.1073	10105.	0.0603	9291.	0.1553
954488.	292000.	102.	329.0	0.108	21.3	13700.	0.545	20970.	
10419.	43571.	12239.	0.1225	11985.	0.1471	12354.	0.1126	12015.	0.1432
954488.	292000.	95.	324.0	0.160	18.2	16000.	0.351	19406.	
13079.	64525.	14384.	0.1172	14120.	0.1365	14450.	0.1109	14362.	0.1189
954488.	292000.	91.	321.0	0.183	14.4	20300.	0.297	18681.	
14262.	75946.	15433.	0.3200	15124.	0.3456	15437.	0.3189	15421.	0.3214

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

954486.	292000.	88.	319.0	0.193	14.5	20200.	0.276	18316.	
14806.	83910.	15935.	0.2716	15587.	0.2990	15897.	0.2742	15907.	0.2744
954449.	292000.	83.	316.0	0.212	14.7	19900.	0.244	17673.	
15792.	96947.	16850.	0.1840	16449.	0.2150	16748.	0.1912	16792.	0.1887
954458.	292000.	81.	315.0	0.229	13.3	22000.	0.222	17224.	
16593.	106541.	17527.	0.2609	17172.	0.2860	17453.	0.2634	17518.	0.2593
954488.	292900.	76.	312.0	0.231	12.7	23100.	0.215	16979.	
16853.	114091.	17740.	0.3078	17389.	0.3330	17685.	0.3125	17746.	0.3052
954456.	292000.	75.	311.0	0.237	11.5	25400.	0.208	16781.	
17179.	119617.	18029.	0.4146	17679.	0.4413	17967.	0.4201	18035.	0.4119
954488.	292000.	70.	308.0	0.248	10.3	28400.	0.193	16349.	
17867.	133865.	18642.	0.5290	18295.	0.5564	18571.	0.5354	18647.	0.5302
940074.	352000.	109.	334.0	0.028	29.6	11900.	2.058	22914.	
5391.	17995.	9711.	0.2286	9382.	0.2707	9882.	0.2055	8282.	0.4410
940074.	352000.	108.	333.0	0.063	27.1	13000.	0.946	22003.	
7797.	28369.	10810.	0.2065	10776.	0.2083	11247.	0.1572	10142.	0.2858
940074.	352000.	104.	330.0	0.132	23.9	14700.	0.446	20169.	
11415.	48780.	13350.	0.1042	13293.	0.1096	13710.	0.0756	13181.	0.1182
940074.	352000.	95.	324.0	0.195	18.7	18800.	0.282	18317.	
14455.	75241.	15846.	0.1911	15683.	0.2024	16069.	0.1738	15862.	0.1904
940074.	352000.	90.	320.0	0.223	17.0	20700.	0.236	17439.	
15870.	92824.	17090.	0.2148	16864.	0.2307	17234.	0.2048	17125.	0.2133
940074.	352000.	86.	318.0	0.235	17.3	20400.	0.219	17032.	
16477.	101423.	17582.	0.1633	17374.	0.1770	17744.	0.1530	17668.	0.1586

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

940074.	352000.	81.	315.0	0.259	16.1	21900.	0.192	16303.	
17653.	119005.	18627.	0.1811	18400.	0.1954	18754.	0.1707	18727.	0.1730
940074.	352000.	78.	313.0	0.265	14.9	23600.	0.184	16045.	
18032.	127020.	18950.	0.2501	18721.	0.2656	19077.	0.2401	19061.	0.2416
940074.	352000.	72.	309.0	0.282	13.5	26100.	0.166	15433.	
19031.	148526.	19876.	0.3179	19598.	0.3361	19946.	0.3147	19947.	0.3116
940074.	352000.	63.	304.0	0.302	12.3	28600.	0.147	14720.	
20301.	181523.	21297.	0.3467	20734.	0.3862	21046.	0.3640	21064.	0.3633
943660.	500000.	130.	347.0	0.026	30.5	16400.	2.392	24063.	
5110.	14224.	11161.	0.4727	11486.	0.4264	11803.	0.3878	9021.	0.8227
943660.	500000.	127.	345.0	0.076	28.7	17400.	0.650	22671.	
8313.	26218.	12207.	0.4299	13118.	0.3315	13460.	0.2970	11389.	0.5327
943660.	500000.	120.	341.0	0.174	27.5	18200.	0.356	20010.	
12905.	50449.	15234.	0.1980	15970.	0.1430	16331.	0.1174	15168.	0.2032
943660.	500000.	109.	334.0	0.253	26.2	19100.	0.212	17436.	
16717.	83693.	18301.	0.0474	18732.	0.0231	19131.	0.0018	18507.	0.0370
943660.	500000.	102.	329.0	0.302	23.4	21400.	0.173	16219.	
15494.	107073.	19529.	0.0922	20103.	0.0678	20524.	0.0461	20081.	0.0700
943660.	500000.	98.	326.0	0.319	21.9	22800.	0.153	15663.	
19324.	121448.	20677.	0.1082	20769.	0.1009	21200.	0.0789	20830.	0.0987
943660.	500000.	91.	321.0	0.351	22.0	22700.	0.134	14671.	
20943.	153118.	22113.	0.0305	22111.	0.0291	22538.	0.0100	22279.	0.0221
943660.	500000.	86.	318.0	0.362	20.6	24300.	0.126	14255.	
21614.	169684.	22468.	0.0854	22664.	0.0774	23095.	0.0550	22872.	0.0655

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

943660.	500000.	78.	313.0	0.383	18.4	27200.	0.113	13521.	
22840.	202176.	23373.	0.1673	23689.	0.1527	24127.	0.1300	23956.	0.1382
943660.	500000.	75.	311.0	0.392	18.2	27500.	0.108	13216.	
23383.	217433.	23852.	0.1562	24161.	0.1422	24500.	0.1234	24444.	0.1305
943660.	500000.	63.	304.0	0.411	15.6	22100.	0.095	12465.	
24909.	273280.	25165.	0.2815	25466.	0.2636	25870.	0.2456	25754.	0.2510
972462.	436000.	117.	339.0	0.024	32.1	13600.	2.392	24208.	
5201.	16192.	10454.	0.3040	10465.	0.2995	10935.	0.2432	8670.	0.5729
972462.	436000.	115.	338.0	0.064	31.4	13900.	0.961	23152.	
7993.	27449.	11522.	0.2103	11983.	0.1657	12435.	0.1224	10762.	0.2957
972462.	436000.	111.	335.0	0.143	27.2	15600.	0.423	20969.	
12031.	49587.	14293.	0.0952	14636.	0.0692	15064.	0.0385	14157.	0.1049
972462.	436000.	101.	328.0	0.219	22.7	19200.	0.254	18641.	
15669.	81087.	17213.	0.1196	17312.	0.1127	17744.	0.0858	17303.	0.1148
972462.	435000.	80.	314.0	0.305	17.0	25700.	0.155	15756.	
20140.	155134.	21253.	0.2138	20998.	0.2292	21413.	0.2029	21290.	0.2106
972462.	435000.	92.	322.0	0.268	18.1	24100.	0.192	17111.	
16031.	113043.	19247.	0.2554	19264.	0.2544	19681.	0.2283	19441.	0.2442
972462.	436000.	67.	306.0	0.331	15.6	28000.	0.132	14706.	
21913.	205389.	22725.	0.2356	22521.	0.2470	22929.	0.2267	22849.	0.2310
965251.	561000.	137.	351.0	0.028	27.6	20300.	2.263	24877.	
5350.	14253.	11800.	0.7242	12497.	0.6226	12722.	0.5930	9545.	1.1323
965251.	561000.	127.	345.0	0.083	33.0	17000.	0.782	23020.	
8824.	28297.	12803.	0.3320	14076.	0.2121	14446.	0.1804	12079.	0.4119

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

965261.	561000.	120.	341.0	0.190	29.4	19100.	0.323	20076.	
13790.	55782.	16116.	0.1883	17140.	0.1175	17532.	0.0922	16173.	0.1843
965261.	561000.	113.	337.0	0.287	27.5	20400.	0.194	17442.	
17773.	89933.	19399.	0.0552	20079.	0.0195	20465.	0.0003	19680.	0.0416
965261.	561000.	104.	330.0	0.350	23.1	24300.	0.143	15508.	
20545.	130034.	22159.	0.1016	22229.	0.0964	22654.	0.0761	22158.	0.1008
965261.	561000.	91.	321.0	0.397	21.5	26100.	0.112	13944.	
23066.	186053.	23755.	0.1024	24294.	0.0768	24737.	0.0580	24427.	0.0716
965261.	561000.	68.	307.0	0.447	14.7	38200.	0.085	12112.	
26458.	294922.	26538.	0.4460	27123.	0.4122	27561.	0.3917	27386.	0.4002
968929.	567000.	140.	353.0	0.033	29.4	19300.	1.977	25012.	
5712.	15006.	11963.	0.6170	12832.	0.5026	12997.	0.4833	9845.	0.9657
968929.	567000.	137.	351.0	0.089	27.9	20300.	0.755	23401.	
9033.	27004.	13060.	0.5594	14505.	0.4044	14715.	0.3839	12314.	0.6538
968929.	567000.	115.	338.0	0.297	26.0	21800.	0.187	17326.	
19145.	92307.	19753.	0.1073	20449.	0.0697	20814.	0.0510	20040.	0.0929
968929.	567000.	104.	330.0	0.359	21.9	25900.	0.138	15351.	
20939.	135076.	22407.	0.1610	22601.	0.1493	23023.	0.1286	22536.	0.1535
968929.	567000.	83.	316.0	0.427	16.8	33700.	0.098	13045.	
24769.	228592.	25280.	0.3367	25746.	0.3143	26191.	0.2897	25949.	0.3019
968929.	567000.	68.	307.0	0.455	13.9	40800.	0.083	11982.	
26361.	303956.	26878.	0.5247	27515.	0.4868	27945.	0.4658	27772.	0.4745
983330.	622000.	147.	357.0	0.041	27.6	22500.	1.659	25504.	
6231.	15970.	12515.	0.8022	13938.	0.6129	13988.	0.6071	10558.	1.1370

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

983330.	622000.	144.	355.0	0.102	27.0	23000.	0.676	23726.	
9677.	28159.	13799.	0.6722	15647.	0.4748	15749.	0.4650	13099.	0.7514
983330.	622000.	135.	350.0	0.218	26.2	23700.	0.293	20324.	
14685.	54704.	17112.	0.3885	18618.	0.2763	18832.	0.2616	17232.	0.3792
983330.	622000.	122.	342.0	0.325	27.4	22700.	0.170	17097.	
19085.	96099.	20746.	0.0977	21685.	0.0504	22011.	0.0343	21088.	0.0815
983330.	622000.	108.	333.0	0.391	23.1	26900.	0.124	14960.	
22132.	145176.	23222.	0.1634	23987.	0.1248	24396.	0.1062	23806.	0.1341
983330.	622000.	98.	319.0	0.464	18.0	34600.	0.087	12533.	
26201.	246247.	26521.	0.3091	27310.	0.2724	27751.	0.2493	27443.	0.2638
983330.	622000.	73.	310.0	0.494	14.5	42900.	0.074	11421.	
29374.	325053.	28203.	0.5276	29125.	0.4772	29571.	0.4568	29347.	0.4673
1480294.	658000.	176.	371.0	0.031	47.7	13800.	2.290	40421.	
7538.	16797.	13343.	0.0370	15661.	-0.1190	15302.	-0.0982	11817.	0.1712
1480294.	658000.	172.	369.0	0.113	37.4	17600.	0.663	36795.	
13579.	36089.	16563.	0.0656	18966.	-0.0706	18708.	-0.0577	16567.	0.0656
1480294.	658000.	162.	364.0	0.172	36.4	18100.	0.415	33833.	
17099.	59217.	19209.	-0.0533	21171.	-0.1426	21060.	-0.1380	19573.	-0.0729
1480294.	658000.	147.	357.0	0.227	29.1	22600.	0.291	30938.	
20385.	90736.	22099.	0.0257	23432.	-0.0322	23465.	-0.0335	22470.	0.0105
1480294.	658000.	130.	347.0	0.281	24.2	27200.	0.212	27859.	
23795.	139777.	25272.	0.0804	25950.	0.0514	26148.	0.0436	25526.	0.0694
1480294.	658000.	115.	338.0	0.308	19.8	33300.	0.178	26055.	
26012.	168548.	27281.	0.2241	27666.	0.2068	27956.	0.1945	27513.	0.2139

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

1480294.	653000.	106.	332.0	0.325	15.2	43400.	0.160	24873.	
27402.	225400.	28684.	0.5203	28786.	0.5152	29115.	0.4944	28761.	0.5129
1480294.	661000.	174.	370.0	0.111	49.3	13400.	0.679	36990.	
13426.	36687.	16486.	-0.1847	18942.	-0.2916	18654.	-0.2806	16458.	-0.1833
1480294.	661000.	164.	365.0	0.171	40.3	16400.	0.420	33976.	
16995.	57749.	19142.	-0.1392	21159.	-0.2227	21024.	-0.2176	19498.	-0.1567
1480294.	661000.	160.	363.0	0.192	40.3	16400.	0.365	32918.	
18200.	67209.	20144.	-0.1825	21970.	-0.2512	21884.	-0.2482	20553.	-0.2001
1480294.	661000.	142.	354.0	0.243	32.4	20400.	0.264	30009.	
21389.	103651.	23069.	-0.1135	24165.	-0.1529	24255.	-0.1560	23372.	-0.1234
1480294.	661000.	120.	341.0	0.296	18.6	35600.	0.191	26759.	
25089.	168218.	26429.	0.3514	26937.	0.3253	27207.	0.3124	26683.	0.3382
1480294.	661000.	115.	338.0	0.311	23.4	28300.	0.176	25942.	
26165.	190780.	27434.	0.0345	27816.	0.0200	28106.	0.0099	27663.	0.0250
1480294.	661000.	105.	331.0	0.326	19.3	34300.	0.159	24748.	
27549.	230782.	28848.	0.1946	28910.	0.1922	29250.	0.1756	28897.	0.1900
1977393.	165000.	62.	303.0	0.016	16.0	6580.	2.762	43477.	
8361.	46994.	8567.	-0.2300	8593.	-0.2320	8765.	-0.2457	8938.	-0.2615
1977393.	105000.	60.	302.0	0.020	14.6	7180.	2.239	43139.	
9178.	53801.	9298.	-0.2242	9361.	-0.2294	9502.	-0.2416	9666.	-0.2554
1977393.	105000.	59.	299.0	0.028	10.6	9870.	1.638	42244.	
10576.	67594.	10691.	-0.0738	10688.	-0.0742	10786.	-0.0807	10917.	-0.0929
1977393.	105000.	56.	293.0	0.042	8.3	12600.	1.072	40565.	
12923.	97689.	13054.	-0.0311	12941.	-0.0250	12962.	-0.0250	12989.	-0.0276

DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

1977393.	105000.	52.	284.0	0.056	6.8	15500.	0.758	38479.	
15316.	146157.	15100.	0.0313	15316.	0.0120	15316.	0.0120	15316.	0.0120
1977393.	150000.	58.	297.0	0.039	9.9	15200.	1.186	41405.	
12340.	86271.	12662.	0.2039	12517.	0.2185	12673.	0.2023	12818.	0.1907
1977393.	150000.	56.	293.0	0.042	11.9	12600.	1.072	40565.	
12923.	97689.	13221.	-0.0446	13058.	-0.0327	13199.	-0.0407	13315.	-0.0507
1977393.	150000.	55.	290.0	0.048	9.8	15300.	0.929	39812.	
13853.	113418.	13933.	0.1030	13941.	0.1009	14041.	0.0931	14127.	0.0879

AVERAGE DEVIATIONS FOR THE DATA OF: SCHROCK AND GROSSMAN, SERIES 'A'

CHEN CORRELATION: 0.2096

HALL-TRAVISS FC/ROHSENOW NB: 0.2034

HALL-TRAVISS FC/MIKIC NB: 0.1902

HALL-TRAVISS FC/THOM NB: 0.2302

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DATA OF:  SCHROCK AND GROSSMAN, SERIES 'E'
TYPE OF FLUID:  WATER
FLOW ORIENTATION:  VERTICAL UPFLOW
TUBE DIAMETER:   0.1130 IN.
MAX ASSUMED ACTIVE CAVITY SIZE:  0.000010 FT.
NUMBER OF DATA POINTS:   50
CSF= 0.0288
B= 0.0000213
W= 0.132


KEY TO REDUCED DATA

FIRST ROW:   G(LBM/HR-FT**2), Q/A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR
             QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
             MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER
SECOND ROW:  HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
             INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDICTED BY CHEN,
             DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSENOW NB,
             DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC NB,
             DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM NB,
             DEVIATION OF H-T/T
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DATA OF: SCHROCK AND GROSSMAN, SERIES 'F'

1250641.	252000.	204.	383.0	0.027	35.5	7099.	2.834	36031.	
6065.	11000.	9732.	-0.2585	9646.	-0.2614	9322.	-0.2351	8433.	-0.1555
1250641.	252000.	200.	381.7	0.083	22.6	11455.	0.971	33837.	
9868.	20598.	12114.	-0.0515	12106.	-0.0510	11861.	-0.0311	11575.	-0.0076
1220603.	459000.	109.	334.1	0.051	39.6	11591.	1.167	29502.	
8650.	31895.	11323.	-0.0247	12483.	-0.0704	13057.	-0.1080	11388.	0.0211
1220603.	459000.	105.	331.2	0.097	33.8	13580.	0.615	27783.	
11894.	50901.	14077.	-0.0325	14592.	-0.0665	15121.	-0.0996	14075.	-0.0325
1220603.	459000.	80.	314.3	0.199	19.3	23844.	0.259	23173.	
18574.	131917.	13792.	0.2162	13684.	0.2144	20210.	0.1834	19938.	0.2001
1250641.	356000.	301.	417.2	0.021	40.4	21188.	4.316	39594.	
5189.	5042.	16036.	0.3241	19309.	0.0944	17620.	0.2009	11871.	0.7987
1250641.	855000.	283.	411.9	0.325	38.3	22349.	0.255	26952.	
18203.	37604.	21332.	0.0501	25813.	-0.1331	24491.	-0.0857	21745.	0.0308
1250641.	356000.	293.	414.8	0.247	39.4	21726.	0.366	30277.	
15555.	27344.	19220.	0.1337	24362.	-0.1046	22870.	-0.0491	19559.	0.1143
2351226.	397000.	202.	382.4	0.024	40.0	9925.	3.148	67936.	
9615.	19726.	12447.	-0.2000	13868.	-0.2835	13460.	-0.2615	12190.	-0.1833
2351226.	397000.	192.	378.3	0.064	24.5	16237.	1.224	64334.	
14643.	38274.	16299.	0.0012	17282.	-0.0573	17014.	-0.0424	16505.	-0.0139
2361238.	897000.	293.	415.0	0.068	49.5	18121.	1.417	70787.	
13931.	22767.	19086.	0.0052	23931.	-0.2412	22374.	-0.1873	18398.	-0.0119
2361238.	897000.	270.	407.8	0.175	34.3	26152.	0.521	61559.	
22070.	57963.	24439.	0.0740	28641.	-0.0849	27468.	-0.0452	25217.	0.0397

DATA OF: SCHROCK AND GROSSMAN, SERIES 'E'

2221165.	1300000.	275.	409.4	0.031	57.0	22807.	2.882	68299.	
3686.	14410.	13144.	0.2601	26262.	-0.1309	24204.	-0.0602	16641.	0.3742
2221165.	1300000.	219.	389.2	0.270	43.8	29680.	0.285	48842.	
27890.	114833.	30359.	-0.0198	35408.	-0.1596	34415.	-0.1350	31244.	-0.0478
3181505.	744000.	190.	377.4	0.095	33.4	22275.	0.828	83966.	
22512.	66953.	23815.	-0.0620	26427.	-0.1543	26040.	-0.1416	24812.	-0.0981
3011524.	1450000.	293.	415.0	0.122	57.0	25439.	0.793	85051.	
22099.	53324.	25123.	0.0150	34626.	-0.2624	32501.	-0.2165	27012.	-0.0554
3011524.	1450000.	196.	380.0	0.283	31.0	46774.	0.255	63413.	
37634.	232932.	40204.	0.1670	43301.	0.0839	42669.	0.1000	40375.	0.1627
2351226.	185000.	132.	348.0	0.072	10.0	18500.	0.914	58184.	
16649.	69145.	17099.	0.0860	17032.	0.0890	17058.	0.0859	17296.	0.0743
2351226.	185000.	156.	361.3	0.022	20.9	8852.	3.017	63941.	
9672.	25865.	10636.	-0.1655	10855.	-0.1817	10837.	-0.1804	10893.	-0.1854
2361107.	799000.	359.	433.8	0.035	35.9	22256.	2.938	76659.	
11212.	11559.	16382.	0.3624	21572.	0.0313	19732.	0.1284	15466.	0.4434
2361107.	799000.	225.	391.8	0.403	13.0	61462.	0.169	42770.	
36475.	190241.	33657.	0.5965	38861.	0.5855	38443.	0.6026	38098.	0.6214
2361107.	799000.	322.	423.7	0.210	28.0	28536.	0.464	61287.	
23181.	53169.	25458.	0.1244	29004.	-0.0134	27747.	0.0318	26102.	0.0959
1430734.	623000.	282.	411.5	0.157	31.9	19622.	0.548	38470.	
13879.	23625.	17139.	0.1483	20343.	-0.0345	19253.	0.0208	17143.	0.1481
1430734.	623000.	267.	406.5	0.273	26.8	23246.	0.310	32759.	
18721.	42247.	21012.	0.1107	23400.	-0.0038	22547.	0.0343	21279.	0.0952

DATA OF: SCHROCK AND GROSSMAN, SERIES 'F'

1510434.	579000.	306.	418.9	0.047	48.7	13943.	2.059	46754.	
8253.	10401.	14719.	-0.0502	18314.	-0.2393	16880.	-0.1741	13105.	0.0671
1410703.	553000.	314.	421.3	0.060	24.8	26330.	1.653	43314.	
8621.	10687.	14779.	0.7365	18220.	0.4445	16793.	0.5684	13279.	0.9887
1410703.	553000.	282.	411.7	0.346	22.6	28894.	0.234	29442.	
28752.	48917.	23100.	0.2548	25350.	0.1433	24434.	0.1865	23263.	0.2450
1200573.	219000.	114.	337.5	0.023	39.6	5530.	2.502	30242.	
6003.	19557.	8683.	-0.3612	8156.	-0.3208	8431.	-0.3432	7897.	-0.2975
1200578.	219000.	112.	335.7	0.055	26.7	8202.	1.095	29062.	
8811.	32014.	10609.	-0.2246	10160.	-0.1900	10394.	-0.2093	10239.	-0.1968
1160560.	184000.	209.	385.0	0.061	23.3	7897.	1.333	32448.	
8013.	15101.	10205.	-0.2237	9874.	-0.1979	9650.	-0.1790	9548.	-0.1705
1160660.	184000.	205.	383.5	0.163	13.9	13333.	0.492	28804.	
12892.	29423.	14289.	-0.0633	13821.	-0.0326	13692.	-0.0237	13915.	-0.0381
1220603.	143000.	111.	335.5	0.010	41.6	3438.	5.297	30931.	
4422.	14083.	7033.	-0.5098	6042.	-0.4300	6271.	-0.4511	6024.	-0.4275
1220603.	143000.	98.	319.8	0.122	12.3	11654.	0.450	25857.	
13916.	76317.	14507.	-0.1032	14114.	-0.1715	14201.	-0.1754	14376.	-0.1564
2381263.	238000.	193.	378.5	0.049	21.3	11174.	1.581	66236.	
13144.	32235.	14289.	-0.2143	14491.	-0.2263	14339.	-0.2183	14409.	-0.2210
2381263.	238000.	179.	372.4	0.070	15.1	15762.	1.084	63678.	
15642.	45309.	16688.	-0.0528	16597.	-0.0479	16512.	-0.0431	16697.	-0.0523
2381263.	238000.	142.	353.7	0.126	13.9	17122.	0.541	56542.	
21887.	108920.	22543.	-0.2374	22270.	-0.2280	22286.	-0.2284	22483.	-0.2361

DATA OF: SCHROCK AND GROSSMAN, SERIES 'F'

2311176.	774000.	318.	422.5	0.018	47.6	16261.	5.114	74351.	
7943.	9495.	15351.	0.0618	19635.	-0.1738	17990.	-0.0971	13439.	0.2134
2311176.	774000.	298.	416.5	0.140	37.5	20640.	0.694	64166.	
19032.	38740.	21400.	-0.0309	25592.	-0.1920	24344.	-0.1500	22211.	-0.0692
2311176.	774000.	167.	366.5	0.385	32.2	24037.	0.156	40143.	
38133.	281379.	40249.	-0.4009	39703.	-0.3920	39621.	-0.3909	39401.	-0.3876
3281730.	365000.	240.	397.0	0.042	23.1	15844.	2.030	96648.	
15343.	32952.	16386.	-0.0284	17873.	-0.1105	17441.	-0.0884	17124.	-0.0726
3281730.	365000.	216.	388.0	0.078	19.0	19263.	1.068	90837.	
20503.	62902.	21562.	-0.1029	22018.	-0.1226	21780.	-0.1133	21818.	-0.1142
715367.	213000.	130.	247.0	0.040	24.0	8875.	1.591	18254.	
4925.	13618.	8397.	0.0598	7593.	0.1738	7759.	0.1484	7042.	0.2541
715367.	213000.	113.	336.5	0.273	13.6	15662.	0.206	13360.	
13571.	57833.	14724.	0.0672	14220.	0.1067	14344.	0.0945	14499.	0.0339
1180553.	189000.	203.	382.7	0.053	26.2	7200.	1.505	33076.	
7677.	14706.	9385.	-0.2766	9670.	-0.2534	9451.	-0.2359	9281.	-0.2219
1180553.	189000.	179.	372.7	0.190	12.3	15366.	0.390	27521.	
14636.	41026.	15738.	-0.0210	15344.	0.0063	15279.	0.0103	15519.	-0.0068
1160660.	321000.	308.	419.3	0.015	32.0	10031.	5.942	37160.	
4306.	4758.	10933.	-0.0806	10785.	-0.0724	9904.	0.0115	8044.	0.2501
1160660.	321000.	302.	417.7	0.120	27.3	11758.	0.819	33070.	
13148.	13855.	13266.	-0.1108	13982.	-0.1577	13263.	-0.1115	12525.	-0.0584
1160660.	321000.	263.	405.0	0.405	10.9	29450.	0.180	21656.	
19848.	48272.	21409.	0.3812	21319.	0.3854	21004.	0.4056	21141.	0.3977

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DATA OF:  SCHROCK AND GROSSMAN, SERIES 'E'

3751692.   501000.    332.   426.5   0.022   40.5   12366.   4.340   105218.
11293.   14373.   14761. -0.1595   17595. -0.2944   16401. -0.2452   14553. -0.1476

3751692.   501000.    204.   383.0   0.209   14.3   34966.   0.373    76158.
33539.  176888.   34877.  0.0056   34633.  0.0130   34482.  0.0170   34587.  0.0144


AVERAGE DEVIATIONS FOR THE DATA OF:  SCHROCK AND GROSSMAN, SERIES 'E'
     CHEN CORRELATION:     0.1692
     HALL-TRAVISS FC/ROHSENOW NB:     0.1704
     HALL-TRAVISS FC/MIKIC NB:     0.1637
     HALL-TRAVISS FC/THOM NB:     0.1586
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DATA OF:  SCHROCK AND GROSSMAN, SERIES 'F'
TYPE OF FLUID:  WATER
FLOW ORIENTATION:  VERTICAL UPFLOW
TUBE DIAMETER:   0.2380 IN.
MAX ASSUMED ACTIVE CAVITY SIZE:  0.000010 FT.
NUMBER OF DATA POINTS:   38
CSF= 0.0288
B= 0.0000213
W= 0.132


KEY TO REDUCED DATA

FIRST ROW:   G(LBM/HR-FT**2), Q/A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR
             QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
             MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER
SECOND ROW:  HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
             INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDICTED BY CHEN,
             DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSENOW NB,
             DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC NB,
             DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM NB,
             DEVIATION OF H-T/T
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DATA OF: SCHROCK AND GROSSMAN, SERIES 'F'

580398.	733000.	211.	386.0	0.125	31.7	23276.	0.654	30546.	
5613.	9581.	11623.	1.0074	16471.	0.4157	15641.	0.4897	11009.	1.1196
580398.	240000.	102.	328.5	0.027	30.3	7921.	2.044	23439.	
3169.	10572.	6618.	0.1645	6510.	0.1990	7101.	0.1144	5899.	0.3459
580398.	411000.	304.	418.1	0.055	23.8	17269.	1.766	35852.	
3572.	3919.	10027.	0.7258	12037.	0.4329	11010.	0.5730	8224.	1.1043
580398.	411000.	302.	417.7	0.177	24.5	16776.	0.544	31193.	
6118.	7257.	10228.	0.6451	13171.	0.2729	12164.	0.3793	9954.	0.6901
290684.	123000.	203.	385.0	0.057	19.0	6474.	1.422	16461.	
2243.	3552.	5998.	0.0517	5205.	0.2422	4970.	0.3014	4450.	0.4583
290684.	123000.	209.	385.0	0.100	12.5	9840.	0.822	15710.	
2905.	4685.	6059.	0.6279	5534.	0.7791	5307.	0.8564	4905.	1.0113
810587.	339000.	223.	391.0	0.034	32.7	13425.	2.389	47813.	
4031.	6254.	9673.	0.3909	11841.	0.1359	11155.	0.2047	8341.	0.6132
810587.	432000.	222.	390.5	0.094	33.0	13303.	0.901	44730.	
6297.	10519.	10050.	0.3264	12358.	0.0344	12216.	0.0834	9916.	0.3455
809616.	692000.	231.	394.0	0.045	32.3	21424.	1.870	47591.	
4495.	6869.	11498.	0.4672	15734.	0.3594	14744.	0.4516	10152.	1.1149
290684.	223000.	109.	334.1	0.043	32.0	6926.	1.371	14290.	
2211.	6739.	6695.	0.0367	6055.	0.1448	6450.	0.0757	5155.	0.3462
290684.	223000.	109.	334.0	0.183	34.0	6559.	0.323	12195.	
4558.	14951.	7158.	-0.0808	7267.	-0.0949	7624.	-0.1374	6809.	-0.0337
590307.	415000.	221.	390.0	0.045	42.3	9811.	1.828	34327.	
3520.	5445.	9542.	0.0303	11230.	-0.1229	10581.	-0.0706	7839.	0.2543

DATA OF: SCHROCK AND GROSSMAN, SERIES 'F'

590307.	415000.	213.	387.0	0.375	32.0	12969.	0.182	22278.	
10201.	20206.	12055.	0.0786	14599.	-0.1105	14109.	-0.0794	12809.	0.0157
590307.	415000.	221.	390.0	0.141	33.5	12388.	0.595	30876.	
5958.	9907.	9842.	0.2624	12315.	0.0056	11704.	0.0587	9516.	0.3056
585352.	142000.	112.	336.3	0.031	27.5	5164.	1.885	29368.	
3336.	10200.	5354.	-0.1155	5381.	-0.0371	5621.	-0.0730	5193.	-0.0029
585352.	142000.	112.	335.7	0.090	22.5	6311.	0.680	27521.	
5469.	17910.	6360.	-0.0903	6753.	-0.0627	6955.	-0.0902	6857.	-0.0768
584343.	232000.	209.	385.0	0.019	34.5	6725.	3.961	34424.	
2493.	3974.	7723.	-0.1273	7545.	-0.1065	7173.	-0.0611	5730.	0.1761
584348.	232000.	208.	384.7	0.085	31.0	7484.	0.964	32081.	
4665.	7983.	7904.	-0.0504	8574.	-0.1262	8234.	-0.0895	7242.	0.0365
584348.	232000.	206.	384.0	0.175	24.8	9355.	0.457	28870.	
6704.	12252.	8836.	0.0621	9713.	-0.0358	9410.	-0.0044	8799.	0.0655
810555.	364000.	128.	346.0	0.018	43.1	8446.	3.310	42535.	
3462.	9137.	8284.	0.0218	8909.	-0.0560	9217.	-0.0829	7039.	0.2026
810555.	364000.	127.	345.0	0.090	39.2	9286.	0.722	39290.	
6921.	20887.	9298.	0.0020	10730.	-0.1309	11004.	-0.1531	9579.	-0.0276
810555.	364000.	118.	339.9	0.225	26.2	13893.	0.265	32923.	
11479.	43235.	12635.	0.1036	13665.	0.0200	13954.	-0.0013	13337.	0.0444
814538.	135000.	215.	387.5	0.017	23.7	5696.	4.446	48416.	
3105.	4867.	6282.	-0.0911	5933.	-0.0395	5670.	0.0058	5198.	0.0987
814538.	135000.	212.	386.5	0.077	19.4	6959.	1.073	45335.	
5812.	10025.	7548.	-0.0751	7547.	-0.0758	7339.	-0.0493	7292.	-0.0427

DATA OF: SCHROCK AND GROSSMAN, SERIES 'F'

321469.	591000.	199.	381.2	0.036	49.7	11891.	2.147	47060.	
4248.	7462.	10579.	0.1264	13763.	-0.1321	13151.	-0.0930	9273.	0.2851
621469.	591000.	182.	373.9	0.395	33.4	17695.	0.156	28957.	
14351.	39211.	16064.	0.1055	18971.	-0.0653	18626.	-0.0478	17003.	0.0437
821469.	591000.	199.	389.6	0.134	39.5	14962.	0.595	42207.	
7749.	15274.	11074.	0.3555	15318.	-0.0231	14751.	0.0142	11718.	0.2807
828107.	126000.	213.	387.0	0.045	21.0	6000.	1.799	47754.	
4641.	7682.	6673.	-0.0980	6615.	-0.0918	6394.	-0.0602	6257.	-0.0380
439492.	126000.	213.	386.7	0.130	20.7	6087.	0.636	23069.	
4551.	7560.	6718.	-0.0911	6561.	-0.0712	6342.	-0.0397	6192.	-0.0139
439492.	230000.	218.	389.9	0.110	28.0	6214.	0.763	23744.	
4151.	6675.	7748.	0.0630	8366.	-0.0181	7970.	0.0312	6890.	0.1955
439492.	230000.	216.	388.0	0.252	25.4	9055.	0.308	19906.	
6424.	11094.	8730.	0.0407	9587.	-0.0547	9237.	-0.0185	8598.	0.0578
590307.	420000.	221.	390.0	0.035	42.7	9836.	2.314	34686.	
3171.	4655.	9710.	0.0151	11126.	-0.1175	10486.	-0.0629	7649.	0.2885
590307.	420000.	218.	388.7	0.204	31.4	13376.	0.395	28508.	
7231.	12705.	10164.	0.3203	13008.	0.0297	12434.	0.0780	10483.	0.2800
586356.	141000.	114.	337.3	0.030	34.9	4036.	1.955	29556.	
2269.	9920.	5831.	-0.3061	5354.	-0.2438	5582.	-0.2753	5153.	-0.2145
586356.	141000.	113.	336.7	0.067	31.5	4476.	0.913	28367.	
4729.	14966.	6479.	-0.3070	6234.	-0.2805	6442.	-0.3040	6252.	-0.2818
586356.	141000.	112.	336.2	0.098	24.4	5779.	0.527	27375.	
5711.	18719.	7126.	-0.1865	6923.	-0.1627	7114.	-0.1854	7050.	-0.1779

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DATA OF:  SCHROCK AND GROSSMAN, SERIES 'F'

 570455.   459000.    137.   351.0   0.400   33.6   13661.   0.134    18590.
11754.   38626.   13212.  0.0384   15068. -0.0911   15224. -0.1006   14065. -0.0259

 570455.   459000.    145.   356.0   0.162   40.0   11475.   0.421    26395.
 6871.   18037.    9919.  0.1606   12238. -0.0610   12298. -0.0656   10142.  0.1343


AVERAGE DEVIATIONS FOR THE DATA OF:  SCHROCK AND GROSSMAN, SERIES 'F'
     CHEN CORRELATION:    0.2179
     HALL-TRAVISS FC/ROHSENOW NB:    0.1442
     HALL-TRAVISS FC/MIKIC NB:    0.1546
     HALL-TRAVISS FC/THOM NB:    0.2856
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DATA OF: BERTOLETTI AND OTHERS
TYPE OF FLUID: WATER
FLOW ORIENTATION: VERTICAL UPFLOW
TUBE DIAMETER: 0.1955 IN.
MAX ASSUMED ACTIVE CAVITY SIZE: 0.000010 FT.
NUMBER OF DATA POINTS: 64
CSF= 0.0228
B= 0.0000213
W= 0.132

KEY TO REDUCED DATA

FIRST ROW: G(LBM/HR-FT**2), Q/A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF), MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER

SECOND ROW: HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF), INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDICTED BY CHEN, DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSENOW NB, DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC NB, DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM NB, DEVIATION OF H-T/T

DATA OF: BERTOLETTI AND OTHERS

2884695.	120276.	1072.	553.1	0.859	3.5	23970.	0.053	29294.	
34828.	27666.	34698.	-0.0175	35004.	-0.0271	25014.	-0.0272	35829.	-0.0487
2884695.	177526.	1075.	553.4	0.856	4.0	44016.	0.054	29747.	
34745.	27439.	34749.	0.2700	35132.	0.2563	35153.	0.2557	36251.	0.2199
2875194.	23695.	1065.	552.2	0.761	0.5	50736.	0.095	49345.	
32703.	24656.	33343.	0.5238	32703.	0.5514	32703.	0.5514	32703.	0.5514
2875194.	110646.	1057.	551.2	0.605	4.5	24571.	0.182	81193.	
29558.	20383.	30559.	-0.2004	29765.	-0.1716	29773.	-0.1717	30632.	-0.1945
2887545.	160715.	1054.	550.9	0.600	6.2	25765.	0.185	82546.	
29571.	20472.	30984.	-0.1660	30001.	-0.1382	30015.	-0.1335	31126.	-0.1599
2894195.	90564.	1037.	548.3	0.271	5.4	16904.	0.645	150254.	
20963.	10570.	21442.	-0.2086	21253.	-0.2022	21257.	-0.2023	22183.	-0.2357
2894195.	90564.	1017.	546.4	0.305	4.7	19264.	0.548	142508.	
22130.	12166.	22845.	-0.1540	22431.	-0.1389	22429.	-0.1389	23292.	-0.1708
2886593.	208979.	1040.	549.2	0.276	11.3	19471.	0.630	148868.	
21103.	10640.	21392.	-0.1567	22402.	-0.1733	22424.	-0.1741	23735.	-0.2199
2886593.	205979.	1019.	546.6	0.345	9.6	21681.	0.465	133902.	
23375.	13468.	24503.	-0.1124	24461.	-0.1094	24457.	-0.1093	25724.	-0.1532
2894195.	81742.	1033.	548.4	0.207	4.2	19521.	0.884	163294.	
18717.	8450.	19039.	0.0299	18993.	0.0314	18996.	0.0313	19921.	-0.0169
2875194.	392541.	1038.	548.9	0.215	19.1	20546.	0.848	160724.	
18907.	8572.	20410.	0.0106	23186.	-0.1112	23236.	-0.1131	23828.	-0.1350
2884695.	465166.	1038.	549.0	0.156	22.0	21174.	1.206	173328.	
16594.	6595.	18563.	0.1434	22796.	-0.0696	22863.	-0.0723	22720.	-0.0650

DATA OF: BERTOLETTI AND OTHERS

2075194.	137026.	1035.	548.6	0.159	8.9	15419.	1.187	172191.	
16650.	6571.	17287.	-0.1040	17558.	-0.1197	17569.	-0.1202	18811.	-0.1783
2084695.	131010.	1031.	548.1	0.074	9.9	13199.	2.549	189860.	
12354.	3922.	12650.	0.0481	13714.	-0.0342	13724.	-0.0350	14943.	-0.1141
2084695.	569110.	1046.	549.9	0.070	24.7	23027.	2.709	191341.	
12060.	3593.	15273.	0.5126	22034.	0.0463	22162.	0.0401	20488.	0.1270
2065692.	226027.	1032.	548.2	0.028	17.0	13284.	6.422	198103.	
6596.	2294.	11459.	0.1631	13061.	0.0218	13087.	0.0198	13531.	-0.0153
2065692.	226027.	1019.	546.6	0.103	16.1	14004.	1.832	182200.	
13947.	4022.	14851.	-0.0526	16703.	-0.1588	16594.	-0.1584	17690.	-0.2059
2061853.	141705.	1049.	550.3	0.855	4.2	33774.	0.054	21293.	
26827.	16971.	26916.	0.2593	27233.	0.2447	27244.	0.2443	28326.	0.1959
2068979.	132262.	1037.	548.8	0.683	5.3	24853.	0.133	46686.	
24103.	13947.	25483.	-0.0210	24537.	0.0172	24544.	0.0170	25625.	-0.0270
2054725.	365755.	1046.	549.9	0.695	9.1	40401.	0.127	44780.	
26065.	13746.	25322.	0.5661	26864.	0.5090	26921.	0.5058	26029.	0.4453
2059477.	283442.	1034.	548.5	0.492	12.8	22137.	0.271	74379.	
20723.	10353.	22462.	-0.0120	22996.	-0.0341	23019.	-0.0351	24204.	-0.0828
2059003.	216831.	1033.	548.4	0.332	14.0	15627.	0.495	97815.	
17415.	7317.	18790.	-0.1655	19328.	-0.1888	19346.	-0.1895	20569.	-0.2381
2061853.	285674.	1037.	548.8	0.331	16.9	16950.	0.498	98219.	
17393.	7262.	19026.	-0.1061	20339.	-0.1638	20373.	-0.1652	21378.	-0.2047
2067079.	266023.	1038.	548.9	0.242	16.8	15871.	0.740	111605.	
15211.	5570.	16629.	-0.0416	16349.	-0.1323	18387.	-0.1341	19323.	-0.1761

DATA OF: PERPOLAZII AND OTHERS

2061853.	350761.	926.	535.3	0.245	19.3	18196.	0.681	107976.	
15635.	6938.	17366.	0.0526	20026.	-0.0892	19729.	-0.0752	20019.	-0.0882
2054725.	150645.	1031.	548.1	0.166	11.9	12725.	1.126	121822.	
12934.	4228.	14085.	-0.0932	14535.	-0.1215	14547.	-0.1222	15758.	-0.1901
2047125.	296994.	1033.	548.3	0.171	19.3	15379.	1.092	120706.	
13049.	4279.	15014.	0.0269	17387.	-0.1137	17418.	-0.1153	17953.	-0.1406
2054726.	135307.	1029.	547.8	0.102	11.8	11506.	1.855	131051.	
10632.	3122.	11698.	-0.0139	12424.	-0.0707	12433.	-0.0714	13586.	-0.1504
2054726.	515916.	1034.	548.5	0.105	23.0	22421.	1.814	130838.	
10733.	3138.	14583.	0.5425	20310.	0.1047	20370.	0.1014	18861.	0.1919
2061853.	80997.	1021.	546.9	0.029	10.0	8125.	6.237	142067.	
6635.	1667.	8557.	-0.0474	8113.	0.0045	8112.	0.0047	9197.	-0.1137
2061853.	80997.	1016.	546.3	0.066	9.3	8677.	2.850	136493.	
8985.	2502.	9664.	-0.0997	9964.	-0.1263	9959.	-0.1253	11092.	-0.2153
2052326.	277074.	1017.	546.4	0.158	18.3	15191.	1.180	122524.	
12650.	4160.	14541.	0.0412	16734.	-0.0956	16718.	-0.0948	17309.	-0.1247
2052826.	479987.	1031.	548.1	0.035	22.9	20903.	5.245	140890.	
7072.	1779.	13974.	0.4994	17768.	0.1731	17810.	0.1703	15947.	0.3137
1683688.	163923.	1032.	548.2	0.801	6.0	30685.	0.075	23781.	
22146.	11658.	22834.	0.3482	23093.	0.3347	23101.	0.3342	24373.	0.2649
1683688.	110069.	1022.	547.8	0.606	5.7	19288.	0.179	47190.	
13383.	9128.	20558.	-0.0594	19841.	-0.0252	19843.	-0.0254	20922.	-0.0745
1683688.	67737.	1028.	547.7	0.470	4.7	14418.	0.294	63450.	
17284.	7267.	18166.	-0.2030	17507.	-0.1739	17508.	-0.1739	18356.	-0.2120

DATA OF: BERTOLETTI AND OTHERS

1683688.	197040.	1027.	547.6	0.350	13.4	13988.	0.458	77694.
15177.	5636.	16499.	-0.1495	16982.	-0.1735	16989.	-0.1738	18194. -0.2289
1683688.	291009.	1025.	547.4	0.352	18.2	16024.	0.455	77460.
15216.	5677.	17008.	-0.0538	18782.	-0.1443	18789.	-0.1447	19571. -0.1786
1683688.	76568.	1023.	547.1	0.245	6.8	11236.	0.721	90151.
13007.	4321.	13632.	-0.1675	13486.	-0.1591	13486.	-0.1531	14537. -0.2211
1693190.	341726.	1029.	547.9	0.246	21.1	16218.	0.721	90719.
13065.	4310.	15213.	0.0690	18260.	-0.1105	18284.	-0.1117	18509. -0.1210
1682263.	175554.	1024.	547.2	0.167	16.8	10443.	1.117	99502.
11029.	3324.	12705.	-0.1760	13530.	-0.2258	13531.	-0.2259	14553. -0.2801
1683688.	343573.	1022.	547.3	0.156	21.5	16242.	1.127	99820.
11004.	3283.	13229.	0.1731	17159.	-0.0495	17184.	-0.0510	17037. -0.0438
1685598.	272195.	1029.	547.9	0.123	19.5	13957.	1.548	105121.
9729.	2740.	12503.	0.1200	14788.	-0.0517	14809.	-0.0531	15059. -0.0704
1685568.	272195.	1019.	546.6	0.272	17.5	15522.	0.635	86997.
13621.	4791.	15345.	0.0139	17291.	-0.1000	17280.	-0.0994	18004. -0.1351
1683688.	453437.	1028.	547.7	0.126	23.6	19191.	1.500	104602.
9818.	2753.	13758.	0.3733	18608.	0.0320	18632.	0.0307	17456. 0.1023
1119292.	156576.	1029.	547.8	0.590	10.8	14494.	0.190	32604.
13817.	4747.	15246.	-0.0463	15363.	-0.0534	15372.	-0.0533	16593. -0.1239
1128793.	65833.	1023.	547.1	0.422	5.5	11938.	0.348	46293.
11958.	3775.	12818.	-0.0642	12387.	-0.0327	12388.	-0.0327	13395. -0.1067
1127368.	243333.	1024.	547.2	0.422	17.4	14304.	0.348	46220.
11957.	3765.	14047.	0.0210	15697.	-0.0867	15700.	-0.0869	16399. -0.1250

DATA OF: BARTOLETTI AND OTHERS

1124043.	197040.	1024.	547.3	0.252	17.1	10927.	0.698	59659.	
9502.	2671.	11742.	-0.0665	12712.	-0.1387	12716.	-0.1389	13543.	-0.1906
1119292.	121944.	1023.	547.1	0.164	13.9	8799.	1.135	66339.	
7891.	2079.	10018.	-0.1188	10067.	-0.1237	10068.	-0.1237	11097.	-0.2045
1119292.	453437.	1029.	547.9	0.166	24.1	18841.	1.125	66343.	
7920.	2367.	13514.	0.3982	17657.	0.0661	17690.	0.0641	16180.	0.1672
2165652.	135105.	1040.	549.2	0.487	7.0	19271.	0.277	75441.	
20653.	10191.	21951.	-0.1161	21257.	-0.0905	21267.	-0.0903	22449.	-0.1380
1119292.	15111.	1021.	546.9	0.084	2.0	7383.	2.243	72707.	
6032.	1452.	6362.	0.1660	6122.	0.2102	6122.	0.2102	6684.	0.1100
1119292.	153667.	1026.	547.5	0.085	11.5	13363.	2.239	72762.	
6039.	1472.	9731.	0.3771	9741.	0.3765	9748.	0.3754	10380.	0.2908
1119292.	17633.	1018.	546.5	0.038	1.0	17242.	4.806	76331.	
4471.	1943.	5267.	2.2943	4682.	2.7003	4681.	2.7010	5410.	2.1965
1119292.	151023.	1022.	547.0	0.040	11.3	13361.	4.624	76271.	
4541.	1055.	9315.	0.4377	8844.	0.5111	8843.	0.5114	9280.	0.4430
1119292.	149648.	1022.	547.0	0.028	11.3	13249.	6.471	77224.	
3992.	909.	9281.	0.4307	8529.	0.5526	8527.	0.5529	8893.	0.4931
816190.	45302.	1029.	547.8	0.555	3.9	11469.	0.148	19982.	
11290.	3413.	12252.	-0.0603	11521.	0.0003	11523.	0.0002	12364.	-0.0682
918565.	107504.	1024.	547.2	0.652	8.1	13326.	0.149	20220.	
11305.	3451.	12742.	0.0497	12419.	0.0766	12420.	0.0765	13611.	-0.0180
820465.	29296.	1010.	545.6	0.434	3.2	9102.	0.331	32852.	
9422.	2695.	10099.	-0.0336	9561.	-0.0446	9559.	-0.0444	10234.	-0.1069

DATA OF: BERTOLETTI AND OTHERS

820406.	149960.	1023.	547.1	0.432	11.4	13186.	0.336	33066.	
5371.	2626.	11395.	0.1605	11776.	0.1228	11777.	0.1228	12791.	0.0342
817615.	22368.	1024.	547.3	0.250	3.0	7539.	0.706	43529.	
7331.	1833.	7940.	-0.0471	7465.	0.0143	7465.	0.0143	8131.	-0.0683
814764.	131879.	1025.	547.4	0.260	12.9	14865.	0.673	42807.	
7435.	1915.	10709.	0.3926	11547.	0.2927	11554.	0.2920	12086.	0.2335
813814.	149399.	1025.	547.4	0.130	13.6	11012.	1.455	50281.	
6543.	1328.	9578.	0.1529	9340.	0.1818	9346.	0.1811	9943.	0.1103

AVERAGE DEVIATIONS FOR THE DATA OF: BERTOLETTI AND OTHERS
CHEN CORRELATION: 0.2009
HALL-TRAVISS FC/ROHSENOW NB: 0.1845
HALL-TRAVISS FC/MIKIC NB: 0.1842
HALL-TRAVISS FC/THOM NB: 0.2013

DATA OF: SANI
TYPE OF FLUID: WATER
FLOW ORIENTATION: VERTICAL DOWNFLOW
TUBE DIAMETER: 0.7194 IN.
MAX ASSUMED ACTIVE CAVITY SIZE: 0.000010 FT.
NUMBER OF DATA POINTS: 84
CSF= 0.0288
B= 0.0000213
W= 0.132

KEY TO REDUCED DATA

FIRST ROW: G(LBM/HR-FT**2), Q/A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF), MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER

SECOND ROW: HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF), INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDICTED BY CHEN, DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSENOW NB, DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC NB, DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM NB, DEVIATION OF H-T/T

DATA OF: SANI

592069.	13800.	18.	221.1	0.021	4.5	3080.	1.192	53457.	
2968.	51764.	2838.	0.0903	2968.	0.0376	2968.	0.0376	2968.	0.0376
594621.	13500.	19.	223.7	0.026	4.7	2940.	0.938	54222.	
3299.	55523.	3125.	-0.0561	3299.	-0.1089	3299.	-0.1089	3299.	-0.1089
589517.	13600.	20.	227.2	0.026	3.7	3580.	1.004	54882.	
3270.	51925.	3109.	0.1877	3270.	0.1255	3270.	0.1255	3270.	0.1255
589517.	13600.	19.	225.6	0.030	4.0	3360.	0.892	54175.	
3469.	56837.	3272.	0.0299	3469.	-0.0314	3469.	-0.0314	3469.	-0.0314
592069.	13740.	20.	228.6	0.036	3.5	3920.	0.767	55061.	
3798.	53984.	3576.	0.1012	3798.	0.0321	3798.	0.0321	3798.	0.0321
592069.	13800.	21.	231.4	0.044	3.5	3940.	0.649	55479.	
4179.	63436.	3943.	0.0026	4179.	-0.0572	4179.	-0.0572	4179.	-0.0572
592069.	13800.	20.	228.8	0.048	3.8	3630.	0.594	54437.	
4416.	70636.	4170.	-0.1270	4416.	-0.1780	4416.	-0.1780	4416.	-0.1780
583517.	14000.	23.	234.9	0.057	3.7	3780.	0.516	55456.	
4756.	68765.	4531.	-0.1621	4756.	-0.2052	4756.	-0.2052	4756.	-0.2052
589517.	14000.	22.	232.4	0.062	3.5	4000.	0.473	54490.	
4984.	75963.	4741.	-0.1530	4984.	-0.1975	4984.	-0.1975	4984.	-0.1975
589517.	14000.	20.	228.9	0.067	3.1	4510.	0.426	53164.	
5271.	86274.	4991.	-0.0935	5271.	-0.1443	5271.	-0.1443	5271.	-0.1443
586965.	13800.	24.	237.7	0.066	3.0	4600.	0.460	55515.	
5080.	70598.	4846.	-0.0472	5080.	-0.0945	5080.	-0.0945	5080.	-0.0945
590793.	13800.	17.	217.9	0.014	5.7	2420.	1.689	52736.	
2477.	45168.	2375.	0.0225	2477.	-0.0231	2477.	-0.0231	2477.	-0.0231

DATA OF: SANI

590793.	13800.	16.	217.2	0.016	5.3	2600.	1.458	52402.	
2659.	49357.	2529.	0.0311	2659.	-0.0221	2659.	-0.0221	2659.	-0.0221
609933.	13800.	23.	235.5	0.050	3.5	3940.	0.587	57938.	
4553.	64751.	4310.	-0.0834	4553.	-0.1347	4553.	-0.1347	4553.	-0.1347
609933.	13800.	20.	227.6	0.060	3.3	4180.	0.469	54980.	
5114.	45229.	4841.	-0.1335	5114.	-0.1826	5114.	-0.1826	5114.	-0.1826
585965.	49800.	28.	246.7	0.076	8.0	6230.	0.432	57757.	
5322.	64531.	5198.	0.2042	5322.	0.1707	5322.	0.1707	5322.	0.1707
587107.	49800.	24.	237.9	0.095	7.6	6560.	0.326	53909.	
6203.	83796.	5978.	0.1014	6203.	0.0576	6203.	0.0576	6203.	0.0576
589517.	49800.	20.	228.2	0.021	16.4	3040.	1.238	55512.	
2941.	45571.	3084.	-0.0116	2963.	0.0297	3041.	0.0022	3045.	0.0006
583517.	49500.	22.	232.3	0.029	13.5	3660.	0.948	56330.	
3400.	49641.	3428.	0.0724	3400.	0.0764	3400.	0.0764	3400.	0.0764
580517.	49500.	20.	227.0	0.045	10.1	4900.	0.608	54035.	
4296.	69449.	4173.	0.1801	4296.	0.1405	4296.	0.1405	4296.	0.1405
588241.	31100.	24.	237.3	0.053	6.0	4500.	0.567	56307.	
4516.	62177.	4348.	0.0380	4516.	-0.0036	4516.	-0.0036	4516.	-0.0036
588241.	31100.	21.	231.0	0.067	5.9	5260.	0.428	53636.	
5264.	83067.	5030.	0.0493	5264.	-0.0008	5264.	-0.0008	5264.	-0.0008
589517.	31400.	26.	241.0	0.069	6.4	4930.	0.455	56610.	
5151.	67901.	4967.	-0.0035	5151.	-0.0430	5151.	-0.0430	5151.	-0.0430
590793.	31600.	21.	230.1	0.031	8.4	3770.	0.892	55733.	
3505.	53547.	3411.	0.1085	3505.	0.0755	3505.	0.0755	3505.	0.0755

DATA OF: SANT

597793.	31600.	19.	225.4	0.041	6.9	4580.	0.658	53590.	
4100.	68602.	3922.	0.1723	4100.	0.1171	4100.	0.1171	4100.	0.1171
597173.	31400.	18.	220.6	0.021	10.6	2970.	1.192	53766.	
2986.	52564.	2978.	0.0016	2986.	-0.0055	2986.	-0.0055	2986.	-0.0055
592069.	31400.	23.	236.0	0.037	7.6	4110.	0.780	57213.	
3804.	52509.	3685.	0.1209	3804.	0.0804	3804.	0.0804	3804.	0.0804
592069.	31400.	20.	228.1	0.054	7.2	4340.	0.515	53834.	
4737.	77294.	4539.	-0.0395	4737.	-0.0837	4737.	-0.0837	4737.	-0.0837
594621.	31600.	26.	241.2	0.071	6.2	5100.	0.446	57071.	
5246.	69124.	5054.	0.0130	5246.	-0.0279	5246.	-0.0279	5246.	-0.0279
593345.	31400.	20.	227.2	0.025	8.8	3570.	1.045	55301.	
3221.	51077.	3189.	0.1233	3221.	0.1085	3221.	0.1085	3221.	0.1085
593558.	31400.	19.	223.3	0.036	7.1	4430.	0.723	53426.	
3891.	67029.	3724.	0.1947	3891.	0.1384	3891.	0.1384	3891.	0.1384
763055.	30900.	21.	231.6	0.019	8.9	3470.	1.395	73409.	
3449.	51091.	3303.	0.0537	3449.	0.0062	3449.	0.0062	3449.	0.0062
763055.	30900.	20.	227.5	0.029	7.2	4300.	0.923	70977.	
4232.	68710.	3995.	0.0901	4232.	0.0162	4232.	0.0162	4232.	0.0162
759227.	31400.	26.	240.7	0.037	7.1	4430.	0.814	75273.	
4593.	59868.	4354.	0.0204	4593.	-0.0355	4593.	-0.0355	4593.	-0.0355
759439.	31400.	23.	234.2	0.049	6.5	4840.	0.596	71810.	
5398.	30541.	5093.	-0.0464	5398.	-0.1034	5398.	-0.1034	5398.	-0.1034
398116.	31300.	20.	226.6	0.060	7.9	3950.	0.463	35654.	
3622.	58651.	3586.	0.1069	3622.	0.0905	3622.	0.0905	3622.	0.0905

DATA OF: SANI

399392.	31400.	21.	230.8	0.093	6.9	4560.	0.313	35392.	
4599.	71466.	4482.	0.0223	4599.	-0.0085	4599.	-0.0085	4599.	-0.0085
399392.	31400.	20.	228.1	0.100	6.7	4690.	0.284	34556.	
4853.	79453.	4730.	-0.0043	4853.	-0.0335	4853.	-0.0335	4853.	-0.0335
399392.	31400.	19.	224.2	0.109	5.5	5720.	0.253	33419.	
5170.	90990.	5045.	0.1376	5170.	0.1064	5170.	0.1064	5170.	0.1064
399392.	31200.	21.	229.5	0.078	7.2	4340.	0.365	35690.	
4194.	65937.	4097.	0.0627	4194.	0.0349	4194.	0.0349	4194.	0.0349
399392.	31200.	19.	223.5	0.095	6.5	4810.	0.290	33814.	
4762.	83798.	4626.	0.0442	4762.	0.0101	4762.	0.0101	4762.	0.0101
398116.	31400.	20.	227.5	0.066	8.0	3930.	0.427	35632.	
3801.	60970.	3743.	0.0546	3801.	0.0340	3801.	0.0340	3801.	0.0340
398116.	31400.	19.	225.1	0.073	7.7	4080.	0.378	34838.	
4067.	68318.	3972.	0.0309	4067.	0.0032	4067.	0.0032	4067.	0.0032
398116.	31400.	18.	222.3	0.081	6.9	4560.	0.334	33967.	
4355.	77320.	4228.	0.0316	4355.	0.0470	4355.	0.0470	4355.	0.0470
400667.	31400.	19.	224.7	0.050	9.0	3490.	0.537	35834.	
3331.	55183.	3322.	0.0537	3331.	0.0477	3331.	0.0477	3331.	0.0477
400667.	31400.	18.	222.9	0.058	8.5	3700.	0.467	35183.	
3600.	61930.	3557.	0.0455	3600.	0.0277	3600.	0.0277	3600.	0.0277
400667.	31400.	18.	220.5	0.065	7.5	4190.	0.406	34407.	
3890.	70340.	3801.	0.1067	3890.	0.0771	3890.	0.0771	3890.	0.0771
404496.	31400.	18.	222.5	0.038	9.8	3210.	0.690	36176.	
2907.	49388.	2952.	0.0920	2907.	0.1043	2907.	0.1043	2907.	0.1043

DATA OF: SANI

400667.	31400.	17.	218.0	0.044	7.9	3980.	0.578	34686.	
3160.	58583.	3156.	0.2653	3160.	0.2596	3160.	0.2596	3160.	0.2596
399392.	46000.	24.	237.4	0.070	10.4	4420.	0.436	37568.	
3817.	51433.	3850.	0.1514	3817.	0.1580	3817.	0.1580	3817.	0.1580
399392.	46000.	23.	235.5	0.078	10.0	4600.	0.387	36871.	
4080.	57263.	4058.	0.1336	4080.	0.1274	4080.	0.1274	4080.	0.1274
399392.	46000.	22.	233.2	0.090	9.9	4650.	0.329	35946.	
4473.	66156.	4411.	0.0583	4473.	0.0395	4473.	0.0395	4473.	0.0395
399392.	46000.	21.	230.3	0.101	9.2	5000.	0.287	34993.	
4838.	76434.	4756.	0.0544	4838.	0.0336	4838.	0.0336	4838.	0.0336
399392.	46000.	20.	226.8	0.112	8.2	5610.	0.251	33838.	
5207.	87918.	5120.	0.1009	5207.	0.0775	5207.	0.0775	5207.	0.0775
399392.	46000.	21.	231.3	0.074	10.5	4380.	0.391	36208.	
4036.	61137.	4016.	0.0934	4036.	0.0852	4036.	0.0852	4036.	0.0852
400667.	46000.	21.	230.1	0.067	11.2	4110.	0.429	36398.	
3825.	58947.	3831.	0.0758	3825.	0.0746	3825.	0.0746	3825.	0.0746
400667.	46000.	19.	224.8	0.087	9.0	5110.	0.316	34458.	
4537.	77631.	4447.	0.1532	4537.	0.1262	4537.	0.1262	4537.	0.1262
403219.	46000.	20.	227.3	0.050	11.6	3970.	0.551	36643.	
3316.	52651.	3389.	0.1761	3316.	0.1971	3316.	0.1971	3316.	0.1971
399392.	46000.	18.	223.0	0.048	12.1	3800.	0.558	35461.	
3241.	55099.	3319.	0.1496	3241.	0.1726	3241.	0.1726	3241.	0.1726
399392.	46000.	18.	221.1	0.058	9.9	4650.	0.461	34705.	
3607.	64023.	3620.	0.2985	3607.	0.2892	3607.	0.2892	3607.	0.2892

DATA OF: SANI

399392.	13800.	20.	227.6	0.086	3.4	4060.	0.329	34991.	
4443.	72467.	4271.	-0.0469	4443.	-0.0862	4443.	-0.0862	4443.	-0.0862
398116.	13800.	19.	225.2	0.065	3.5	3950.	0.424	35167.	
3801.	63281.	3662.	0.0831	3801.	0.0391	3801.	0.0391	3801.	0.0391
398116.	13800.	18.	220.6	0.074	2.9	4760.	0.359	33886.	
4157.	75607.	3982.	0.1992	4157.	0.1450	4157.	0.1450	4157.	0.1450
400667.	13800.	18.	222.9	0.051	4.1	3370.	0.520	35415.	
3383.	57849.	3274.	0.0321	3383.	-0.0039	3383.	-0.0039	3383.	-0.0039
400667.	13800.	17.	219.0	0.060	3.6	3800.	0.436	34313.	
3718.	68740.	3572.	0.0685	3718.	0.0220	3718.	0.0220	3718.	0.0220
396839.	46000.	22.	233.3	0.096	9.0	5110.	0.310	35586.	
4615.	67804.	4550.	0.1271	4615.	0.1073	4615.	0.1073	4615.	0.1073
400667.	31400.	21.	230.5	0.089	6.3	4990.	0.326	35614.	
4494.	70029.	4378.	0.1427	4494.	0.1104	4494.	0.1104	4494.	0.1104
183746.	31400.	17.	219.9	0.117	8.6	3650.	0.228	14859.	
2898.	51531.	3044.	0.2036	2898.	0.2594	2898.	0.2594	2898.	0.2594
183746.	31400.	16.	216.7	0.143	7.2	4360.	0.179	14150.	
3340.	63779.	3400.	0.2858	3340.	0.3054	3340.	0.3054	3340.	0.3054
585689.	31400.	18.	221.9	0.016	12.5	2520.	1.484	53363.	
2640.	44996.	2686.	-0.0594	2640.	-0.0455	2640.	-0.0455	2640.	-0.0455
586965.	31400.	18.	221.0	0.021	10.9	2880.	1.176	52949.	
2968.	51845.	2971.	-0.0265	2968.	-0.0296	2968.	-0.0296	2968.	-0.0296
585689.	31400.	19.	225.3	0.045	7.3	4310.	0.607	52896.	
4255.	71630.	4069.	0.0628	4255.	0.0129	4255.	0.0129	4255.	0.0129

DATA OF: SANI

580727.	31400.	21.	229.5	0.065	6.6	4760.	0.436	52638.	
5141.	83067.	4915.	-0.0280	5141.	-0.0742	5141.	-0.0742	5141.	-0.0742
592069.	31400.	26.	240.8	0.072	6.9	4620.	0.433	56634.	
5280.	70080.	5082.	-0.0875	5280.	-0.1249	5280.	-0.1249	5280.	-0.1249
592069.	31400.	24.	237.8	0.078	6.1	5150.	0.393	55320.	
5603.	78922.	5367.	-0.0375	5603.	-0.0808	5603.	-0.0808	5603.	-0.0808
398116.	31400.	17.	218.7	0.026	13.7	2300.	0.961	35270.	
2382.	42684.	2541.	-0.0924	2382.	-0.0345	2382.	-0.0345	2382.	-0.0345
398116.	31400.	16.	216.9	0.038	9.0	3490.	0.650	34449.	
2936.	55241.	2965.	0.1921	2936.	0.1885	2936.	0.1885	2936.	0.1885
399392.	31400.	17.	217.6	0.020	15.3	2050.	1.210	35373.	
2115.	38402.	2342.	-0.1222	2115.	-0.0307	2115.	-0.0307	2115.	-0.0307
399392.	31400.	16.	216.1	0.032	9.6	3270.	0.766	34635.	
2684.	50917.	2758.	0.1916	2684.	0.2184	2684.	0.2184	2684.	0.2184
395564.	31400.	18.	222.4	0.041	9.9	3180.	0.641	35243.	
2973.	50697.	3011.	0.0605	2973.	0.0696	2973.	0.0696	2973.	0.0696
396839.	31400.	19.	225.0	0.072	8.0	3930.	0.384	34754.	
4016.	67470.	3926.	0.0047	4016.	-0.0214	4016.	-0.0214	4016.	-0.0214
399392.	31400.	19.	225.9	0.078	7.1	4430.	0.358	34939.	
4216.	70199.	4109.	0.0817	4216.	0.0508	4216.	0.0508	4216.	0.0508
399392.	31400.	18.	223.0	0.086	6.3	4990.	0.317	34034.	
4509.	79436.	4376.	0.1432	4509.	0.1068	4509.	0.1068	4509.	0.1068
403219.	31400.	21.	230.1	0.084	6.8	4630.	0.342	35943.	
4390.	68753.	4278.	0.0853	4390.	0.0546	4390.	0.0546	4390.	0.0546

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DATA OF:  SANI


AVERAGE DEVIATIONS FOR THE DATA OF:  SANI
     CHEN CORRELATION:    0.0947
     HALL-TRAVISS FC/ROHSENOW NB:    0.0879
     HALL-TRAVISS FC/MIKIC NB:    0.0876
     HALL-TRAVISS FC/THOM NB:    0.0875
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DATA OF: WRIGHT #1
TYPE OF FLUID: WATER
FLOW ORIENTATION: VERTICAL DOWNFLOW
TUBE DIAMETER: 0.7194 IN.
MAX ASSUMED ACTIVE CAVITY SIZE: 0.000010 FT.
NUMBER OF DATA POINTS: 67
CSF= 0.0288
B= 0.0000213
W= 0.132

KEY TO REDUCED DATA

FIRST ROW: G(LBM/HR-FT**2), Q/A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF), MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER

SECOND ROW: HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF), INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDICTED BY CHEN, DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSENOW NB, DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC NB, DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM NB, DEVIATION OF H-T/T

DATA OF: WRIGHT #1

587674.	13815.	16.	216.3	0.015	5.2	2677.	1.533	51911.
2578.	48573.	2459.	0.0923	2578.	0.0386	2578.	0.0386	2578. 0.0386
593700.	13815.	17.	219.0	0.022	4.2	3296.	1.117	52894.
3064.	55630.	2942.	0.1249	3064.	0.0756	3064.	0.0756	3064. 0.0756
591927.	13815.	18.	220.7	0.025	3.7	3755.	0.992	53075.
3261.	57737.	3087.	0.2208	3261.	0.1514	3261.	0.1514	3261. 0.1514
589801.	13623.	19.	224.0	0.033	4.0	3365.	0.799	53503.
3671.	62111.	3449.	-0.0195	3671.	-0.0834	3671.	-0.0834	3671. -0.0834
591927.	13751.	19.	225.4	0.041	3.2	4316.	0.650	53665.
4132.	69209.	3984.	0.1150	4132.	0.0444	4132.	0.0444	4132. 0.0444
586611.	13815.	23.	234.8	0.071	2.8	4916.	0.418	54334.
5342.	78707.	5077.	-0.0286	5342.	-0.0797	5342.	-0.0797	5342. -0.0797
610359.	13815.	21.	229.4	0.058	3.3	4224.	0.489	55728.
5014.	80830.	4757.	-0.1088	5014.	-0.1575	5014.	-0.1575	5014. -0.1575
587320.	49888.	26.	242.0	0.086	8.4	5968.	0.371	55687.
5783.	76418.	5592.	0.0720	5783.	0.0319	5783.	0.0319	5783. 0.0319
589446.	49886.	20.	226.5	0.032	10.8	4603.	0.824	54301.
3626.	58810.	3587.	0.2880	3626.	0.2695	3626.	0.2695	3626. 0.2695
589092.	49569.	21.	229.5	0.042	10.1	4893.	0.658	54711.
4118.	64615.	4017.	0.2214	4118.	0.1881	4118.	0.1881	4118. 0.1881
591573.	1503.	16.	217.3	0.026	1.0	1468.	0.949	51989.
3315.	62547.	3049.	-0.5170	3315.	-0.5572	3315.	-0.5572	3315. -0.5572
588383.	31084.	22.	232.8	0.066	6.2	5005.	0.445	54256.
5153.	78324.	4936.	0.0178	5153.	-0.0287	5153.	-0.0287	5153. -0.0287

DATA OF: WRIGHT #1

589801.	31468.	24.	237.8	0.077	5.9	5295.	0.397	55162.	
5549.	78038.	5318.	-0.0011	5549.	-0.0457	5549.	-0.0457	5549.	-0.0457
591219.	31660.	20.	226.8	0.041	7.3	4324.	0.669	54101.	
4073.	66578.	3901.	0.1128	4073.	0.0616	4073.	0.0616	4073.	0.0616
596890.	31468.	18.	220.6	0.021	10.4	3029.	1.192	53741.	
2985.	52542.	2977.	0.0217	2985.	0.0147	2985.	0.0147	2985.	0.0147
591927.	31276.	21.	231.4	0.049	6.9	4521.	0.577	55129.	
4461.	58263.	4277.	0.0602	4461.	0.0134	4461.	0.0134	4461.	0.0134
594054.	31660.	24.	236.4	0.081	5.1	6158.	0.374	54904.	
5773.	83728.	5521.	0.1186	5773.	0.0668	5773.	0.0668	5773.	0.0668
592991.	31468.	19.	224.4	0.034	7.6	4145.	0.784	53876.	
3729.	62768.	3584.	0.1623	3729.	0.1116	3729.	0.1116	3729.	0.1116
762417.	30956.	21.	229.9	0.026	7.9	3900.	1.039	72191.	
3992.	62035.	3815.	0.0265	3992.	-0.0231	3992.	-0.0231	3992.	-0.0231
759227.	31663.	24.	237.9	0.043	7.0	4543.	0.693	73672.	
4993.	68986.	4715.	-0.0321	4993.	-0.0902	4993.	-0.0902	4993.	-0.0902
397690.	31503.	19.	224.6	0.068	7.4	4280.	0.406	34902.	
3893.	65611.	3816.	0.1262	3893.	0.0995	3893.	0.0995	3893.	0.0995
399108.	31468.	20.	228.0	0.101	6.6	4776.	0.280	34457.	
4892.	80307.	4770.	0.0054	4892.	-0.0236	4892.	-0.0236	4892.	-0.0236
399463.	31276.	19.	226.0	0.087	7.1	4389.	0.321	34618.	
4498.	75371.	4372.	0.0065	4498.	-0.0241	4498.	-0.0241	4498.	-0.0241
400171.	31439.	18.	223.0	0.058	8.2	3838.	0.465	35149.	
3606.	61930.	3562.	0.0828	3606.	0.0644	3606.	0.0644	3606.	0.0644

DATA OF: WEIGHT #1

404070.	31433.	18.	221.0	0.047	8.8	3554.	0.557	35482.	
3265.	57502.	3253.	0.0959	3265.	0.0886	3265.	0.0886	3265.	0.0886
399108.	46051.	21.	230.4	0.101	8.7	5272.	0.285	34963.	
4850.	76501.	4769.	0.1087	4850.	0.0871	4850.	0.0871	4850.	0.0871
398754.	46051.	20.	227.1	0.091	9.0	5139.	0.310	34646.	
4587.	75724.	4502.	0.1454	4587.	0.1203	4587.	0.1203	4587.	0.1203
400171.	46051.	20.	227.9	0.077	10.3	4490.	0.366	35461.	
4178.	57305.	4129.	0.0925	4178.	0.0748	4178.	0.0748	4178.	0.0748
399463.	46051.	18.	223.0	0.048	11.7	3921.	0.556	35460.	
3248.	55242.	3326.	0.1839	3248.	0.2070	3248.	0.2070	3248.	0.2070
398754.	13815.	19.	225.1	0.091	3.3	4244.	0.304	34212.	
4630.	79032.	4452.	-0.0427	4630.	-0.0833	4630.	-0.0833	4630.	-0.0833
397690.	13815.	18.	222.9	0.070	3.6	3817.	0.388	34466.	
3987.	69338.	3828.	0.0007	3987.	-0.0427	3987.	-0.0427	3987.	-0.0427
396981.	13815.	18.	221.0	0.056	4.2	3319.	0.473	34538.	
3531.	62658.	3410.	-0.0242	3531.	-0.0601	3531.	-0.0601	3531.	-0.0601
397336.	46051.	21.	229.2	0.114	8.1	5700.	0.252	34091.	
5198.	84508.	5121.	0.1186	5198.	0.0966	5198.	0.0966	5198.	0.0966
590864.	49249.	26.	241.5	0.075	7.9	6261.	0.419	56511.	
5408.	71250.	5242.	0.1975	5408.	0.1576	5408.	0.1576	5408.	0.1576
590510.	13815.	23.	234.0	0.072	3.0	4620.	0.413	54440.	
5404.	80942.	5132.	-0.0970	5404.	-0.1451	5404.	-0.1451	5404.	-0.1451
400171.	31468.	20.	227.7	0.098	6.1	5130.	0.290	34635.	
4793.	78840.	4668.	0.1037	4793.	0.0703	4793.	0.0703	4793.	0.0703

DATA OF: WRIGHT #1

586965.	31468.	18.	221.0	0.021	10.8	2911.	1.171	52944.
2974.	51970.	2978.	-0.0184	2974.	-0.0213	2974.	-0.0213	2974. -0.0213
585193.	31468.	20.	227.8	0.039	7.9	3998.	0.707	53988.
3926.	62909.	3772.	0.0646	3926.	0.0182	3926.	0.0182	3926. 0.0182
580940.	31468.	22.	232.9	0.059	6.8	4602.	0.497	53999.
4791.	71942.	4616.	0.0016	4791.	-0.0395	4791.	-0.0395	4791. -0.0395
592636.	31468.	24.	237.8	0.079	5.9	5300.	0.390	55337.
5631.	79393.	5394.	-0.0144	5631.	-0.0588	5631.	-0.0588	5631. -0.0588
183958.	31436.	18.	221.0	0.130	10.8	2911.	0.205	14740.
3096.	54266.	3205.	-0.0889	3096.	-0.0596	3096.	-0.0596	3096. -0.0596
397690.	31468.	17.	217.9	0.032	11.8	2659.	0.777	34840.
2664.	48814.	2748.	-0.0302	2664.	-0.0018	2664.	-0.0018	2664. -0.0018
397690.	31468.	16.	217.0	0.027	12.6	2500.	0.908	34847.
2445.	45308.	2581.	-0.0289	2445.	0.0223	2445.	0.0223	2445. 0.0223
398754.	31468.	17.	218.5	0.034	10.7	2953.	0.732	34971.
2760.	50155.	2826.	0.0499	2760.	0.0698	2760.	0.0698	2760. 0.0698
396627.	31468.	19.	220.9	0.048	8.8	3576.	0.543	34765.
3260.	57510.	3254.	0.1024	3260.	0.0969	3260.	0.0969	3260. 0.0969
393437.	31275.	19.	223.6	0.063	7.8	4024.	0.429	34482.
3730.	63629.	3670.	0.1015	3730.	0.0789	3730.	0.0789	3730. 0.0789
396627.	31468.	19.	225.0	0.072	7.3	4315.	0.381	34713.
4033.	67803.	3942.	0.0986	4033.	0.0698	4033.	0.0698	4033. 0.0698
399817.	31468.	19.	225.9	0.078	6.9	4542.	0.355	34958.
4235.	70559.	4126.	0.1043	4235.	0.0724	4235.	0.0724	4235. 0.0724

DATA OF: WRIGHT #1

403007.	31463.	19.	225.8	0.097	6.2	5041.	0.288	34512.	
4825.	31882.	4692.	0.0789	4825.	0.0448	4825.	0.0448	4825.	0.0448
595472.	24429.	19.	223.8	0.027	7.0	3497.	0.965	54293.	
3345.	56271.	3225.	0.0871	3345.	0.0454	3345.	0.0454	3345.	0.0454
593700.	24269.	20.	227.0	0.040	6.7	3647.	0.684	54445.	
4038.	65734.	3839.	-0.0470	4038.	-0.0969	4038.	-0.0969	4038.	-0.0969
593700.	24535.	19.	223.8	0.028	6.4	3831.	0.914	54042.	
3433.	57886.	3296.	0.1682	3433.	0.1160	3433.	0.1160	3433.	0.1160
591927.	24429.	22.	232.7	0.056	4.6	5306.	0.518	55115.	
4752.	71529.	4548.	0.1710	4752.	0.1167	4752.	0.1167	4752.	0.1167
591927.	24301.	24.	236.6	0.081	4.3	5692.	0.374	54766.	
5751.	83076.	5488.	0.0417	5751.	-0.0103	5751.	-0.0103	5751.	-0.0103
964097.	44778.	21.	230.8	0.010	15.6	2876.	2.423	93193.	
3212.	48005.	3102.	-0.0705	3212.	-0.1046	3212.	-0.1046	3212.	-0.1046
972959.	45539.	25.	239.5	0.021	12.0	3796.	1.350	97415.	
4334.	57194.	4106.	-0.0732	4334.	-0.1241	4334.	-0.1241	4334.	-0.1241
992453.	45091.	32.	254.1	0.041	8.0	5623.	0.818	105161.	
5814.	63043.	5501.	0.0269	5814.	-0.0328	5814.	-0.0328	5814.	-0.0328
1180311.	45478.	29.	247.7	0.015	9.6	4739.	2.010	124540.	
4247.	49210.	3950.	0.2034	4247.	0.1158	4247.	0.1158	4247.	0.1158
1159044.	44944.	34.	257.2	0.029	8.0	5613.	1.177	126395.	
5492.	56092.	5218.	0.0785	5492.	0.0221	5492.	0.0221	5492.	0.0221
1192007.	30752.	29.	248.3	0.018	7.3	4219.	1.688	125763.	
4655.	54019.	4295.	-0.0147	4655.	-0.0936	4655.	-0.0936	4655.	-0.0936

DATA OF: WRIGHT #1

1201577.	31001.	32.	254.1	0.025	6.1	5085.	1.330	129565.	
5303.	56645.	4927.	0.0366	5303.	-0.0410	5303.	-0.0410	5303.	-0.0410
1166841.	16246.	26.	242.2	0.016	4.7	3478.	1.759	119178.	
4443.	56297.	4022.	-0.1318	4443.	-0.2173	4443.	-0.2173	4443.	-0.2173
974731.	16709.	21.	230.5	0.017	6.4	2599.	1.535	93437.	
4020.	61807.	3672.	-0.2904	4020.	-0.3534	4020.	-0.3534	4020.	-0.3534
323611.	16342.	16.	215.3	0.036	6.8	2401.	0.689	27832.	
2390.	45665.	2407.	0.0013	2390.	0.0046	2390.	0.0046	2390.	0.0046
324320.	16658.	17.	220.2	0.082	4.5	3716.	0.326	27320.	
3717.	67242.	3613.	0.0311	3717.	-0.0003	3717.	-0.0003	3717.	-0.0003
332826.	46134.	18.	221.1	0.059	12.8	3597.	0.453	28890.	
3135.	54913.	3258.	0.1090	3135.	0.1475	3135.	0.1475	3135.	0.1475
320421.	46028.	19.	225.3	0.105	9.7	4735.	0.264	27097.	
4213.	70825.	4218.	0.1274	4213.	0.1240	4213.	0.1240	4213.	0.1240

AVERAGE DEVIATIONS FOR THE DATA OF: WRIGHT #1
CHEN CORRELATION: 0.0938
HALL-TRAVISS FC/ROHSENOW NB: 0.0895
HALL-TRAVISS FC/MIKIC NB: 0.0895
HALL-TRAVISS FC/THOM NB: 0.0895

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DATA OF:  WRIGHT #2
TYPE OF FLUID:  WATER
FLOW ORIENTATION:  VERTICAL DOWNFLOW
TUBE DIAMETER:   0.4716 IN.
MAX ASSUMED ACTIVE CAVITY SIZE:  0.000010 FT.
NUMBER OF DATA POINTS:   39
CSF= 0.0288
B= 0.0000213
W= 0.132


KEY TO REDUCED DATA

FIRST ROW:   G(LBM/HR-FT**2), Q/A(BTU/HR-FT**2), PRESSURE(PSIA), SATURATION TEMP(DEGF), VAPOR
             QUALITY, EXP. WALL SUPERHEAT(DEGF), EXP. HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
             MARTINELLI PARAMETER, LIQUID REYNOLDS NUMBER
SECOND ROW:  HALL-TRAVISS FORCED CONVECTION HEAT TRANSFER COEFFICIENT(BTU/HR-FT**2-DEGF),
             INCIPIENT BOILING HEAT FLUX(BTU/HR-FT**2), HEAT XFER COEFF PREDICTED BY CHEN,
             DEVIATION OF CHEN, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/ROHSENOW NB,
             DEVIATION OF H-T/R, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/MIKIC NB,
             DEVIATION OF H-T/M, HEAT XFER COEFF PRED BY HALL-TRAVISS FC/THOM NB,
             DEVIATION OF H-T/T
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DATA OF: WRIGHT #2

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 870157.     37289.       21.    229.3   0.024      9.6    3899.    1.101     53907.
 4647.    74247.     4529. -0.1348    4647. -0.1610    4647. -0.1610    4647. -0.1610

 870157.     37106.       26.    241.1   0.050      8.1    4585.    0.619     55926.
 6433.    87925.     6140. -0.2502    6433. -0.2872    6433. -0.2872    6433. -0.2872

 849537.     36759.       29.    248.6   0.091      6.0    6173.    0.365     54439.
 8579.   111503.     8249. -0.2493    8579. -0.2804    8579. -0.2804    8579. -0.2804

1794751.     37112.       43.    270.7   0.026      7.5    4951.    1.440    137566.
 7799.    69238.     7254. -0.3155    7799. -0.3652    7799. -0.3652    7799. -0.3652

1740315.     36287.       48.    277.3   0.043      6.7    5400.    0.937    135049.
 9491.    80353.     8995. -0.3977    9491. -0.4310    9491. -0.4310    9491. -0.4310

2313546.     37201.       53.    286.3   0.021      9.4    3951.    1.918    191335.
 8515.    61220.     7724. -0.4918    8515. -0.5360    8515. -0.5360    8515. -0.5360

 870157.     88009.       26.    242.5   0.038     14.2    6182.    0.803     57054.
 5593.    72907.     5526.  0.1221    5642.  0.1004    5802.  0.0681    5827.  0.0536

 870157.     88009.       29.    247.8   0.016     25.1    3503.    1.821     60119.
 3732.    42557.     4108. -0.1447    3965. -0.1145    4499. -0.2201    4509. -0.2205

 870157.     87202.       32.    253.2   0.072     13.5    6481.    0.482     58271.
 7509.    87011.     7362. -0.1172    7509. -0.1369    7511. -0.1369    7512. -0.1369

 870157.     87632.       39.    265.3   0.105     11.1    7909.    0.361     59772.
 8936.    89905.     8761. -0.0939    8936. -0.1149    8936. -0.1149    8936. -0.1149

1795575.     87390.       53.    284.6   0.012     17.7    4935.    3.083    148787.
 5573.    37644.     5313. -0.0669    5825. -0.1489    6105. -0.1893    6247. -0.2067

1795575.     86831.       47.    277.0   0.030     12.3    7060.    1.311    141048.
 8219.    67074.     7816. -0.0943    8280. -0.1443    8376. -0.1535    8456. -0.1628
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DATA OF: WRIGHT #2

1795575.	87655.	58.	297.6	0.049	12.1	7230.	0.948	151300.	
9845.	62569.	9551.	-0.2401	9923.	-0.2686	9993.	-0.2740	10102.	-0.2823
2272306.	86418.	59.	299.1	0.017	13.7	6310.	2.563	199273.	
7444.	42897.	6892.	-0.0802	7622.	-0.1700	7772.	-0.1846	7940.	-0.2029
2249212.	86949.	55.	290.3	0.025	11.7	7459.	1.717	188465.	
8795.	59963.	8277.	-0.0965	8882.	-0.1562	8979.	-0.1653	9093.	-0.1769
490752.	95595.	24.	237.5	0.117	14.0	6171.	0.262	28747.	
6561.	95596.	6567.	-0.0570	6561.	-0.0594	6561.	-0.0594	6561.	-0.0594
490752.	87249.	27.	243.7	0.159	11.8	7376.	0.200	28333.	
7734.	105571.	7691.	-0.0353	7734.	-0.0463	7734.	-0.0463	7734.	-0.0463
490752.	37872.	18.	221.8	0.051	9.8	3845.	0.521	28270.	
4295.	76790.	4283.	-0.0998	4295.	-0.1049	4295.	-0.1049	4295.	-0.1049
490752.	37642.	20.	228.4	0.088	7.5	5023.	0.323	28261.	
5740.	95997.	5603.	-0.0991	5740.	-0.1249	5740.	-0.1249	5740.	-0.1249
870157.	37289.	18.	222.6	0.036	6.0	6217.	0.734	51174.	
5690.	104474.	5364.	0.1520	5690.	0.0926	5690.	0.0926	5690.	0.0926
870157.	37106.	21.	230.6	0.065	6.3	5922.	0.441	52037.	
7686.	131531.	7307.	-0.1862	7686.	-0.2295	7686.	-0.2295	7686.	-0.2295
849537.	36759.	26.	242.3	0.100	4.3	8574.	0.320	52087.	
9199.	134541.	8825.	-0.0259	9199.	-0.0679	9199.	-0.0679	9199.	-0.0679
1794751.	37112.	36.	260.9	0.038	5.2	7153.	0.927	129476.	
9626.	105616.	8999.	-0.2028	9626.	-0.2569	9626.	-0.2569	9626.	-0.2569
1740315.	36287.	39.	265.7	0.057	6.1	5932.	0.656	126210.	
11338.	123030.	10693.	-0.4430	11338.	-0.4768	11338.	-0.4768	11338.	-0.4768

DATA OF: WRIGHT #2

2604698.	35922.	46.	275.8	0.010	8.5	4236.	3.434	207584.	
7151.	57459.	6208.	-0.3145	7151.	-0.4076	7151.	-0.4076	7151.	-0.4076
2313546.	37201.	46.	275.5	0.035	5.4	6841.	1.136	179622.	
10855.	98852.	10275.	-0.3310	10855.	-0.3698	10855.	-0.3698	10855.	-0.3698
870157.	88009.	22.	233.1	0.058	9.6	9191.	0.500	53095.	
7175.	115227.	6949.	0.3263	7175.	0.2810	7175.	0.2810	7175.	0.2810
870157.	87632.	32.	253.2	0.127	7.1	12231.	0.272	54780.	
10408.	132546.	10183.	0.2128	10408.	0.1809	10408.	0.1809	10408.	0.1809
1795575.	86831.	40.	267.0	0.046	8.5	10231.	0.818	132588.	
10352.	106247.	9764.	0.0487	10352.	-0.0117	10352.	-0.0117	10352.	-0.0117
1795575.	37655.	45.	273.5	0.067	3.9	9727.	0.599	133496.	
12290.	121430.	11691.	-0.1650	12290.	-0.2085	12290.	-0.2085	12290.	-0.2085
2272306.	87614.	43.	271.2	0.024	8.4	10484.	1.551	174904.	
9139.	84001.	8488.	0.2405	9149.	0.1472	9169.	0.1472	9184.	0.1442
2272306.	86418.	49.	278.7	0.027	10.2	8471.	1.443	180401.	
9535.	79208.	8914.	-0.0459	9555.	-0.1115	9586.	-0.1140	9620.	-0.1157
2249212.	86949.	49.	279.3	0.041	7.5	11623.	1.002	176622.	
11341.	99347.	10760.	0.0835	11341.	0.0253	11341.	0.0253	11341.	0.0253
490752.	86595.	19.	224.1	0.094	13.7	6300.	0.292	27341.	
6062.	109722.	6030.	0.0492	6062.	0.0393	6062.	0.0393	6062.	0.0393
490752.	86595.	19.	225.9	0.146	11.1	7779.	0.189	26053.	
7884.	146516.	7731.	0.0102	7884.	-0.0133	7884.	-0.0133	7884.	-0.0133
490752.	87249.	22.	231.8	0.188	8.8	9921.	0.151	25650.	
9050.	158110.	8961.	0.1101	9050.	0.0962	9050.	0.0962	9050.	0.0962

DATA OF: WRIGHT #2

```
490752.     37872.      16.   216.3   0.064     6.8    5569.   0.397    26995.
4985.  100514.     4865.  0.1488    4985.  0.1171    4985.  0.1171    4985.  0.1171

490752.     37642.      17.   219.6   0.104     5.6    6700.   0.254    26336.
6539.  129837.     6385.  0.0524    6539.  0.0246    6539.  0.0246    6539.  0.0246

870157.     87202.      26.   241.6   0.094     9.6    9094.   0.339    53500.
9071.  133608.     8740.  0.0437    9071.  0.0025    9071.  0.0025    9071.  0.0025
```

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AVERAGE DEVIATIONS FOR THE DATA OF:  WRIGHT #2
     CHEN CORRELATION:    0.1638
     HALL-TRAVISS FC/ROHSENOW NB:    0.1772
     HALL-TRAVISS FC/MIKIC NB:    0.1812
     HALL-TRAVISS FC/THOM NB:    0.1827
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Thesis 170585
H14775 Hall
A method of correlating forced convection boiling heat transfer data.